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ABSTRACT

This facilitator's guide, and the videotape it accompanies, is designed to demonstrate ways in which the new visions of science education for the 21st century might be translated into classroom practice. The National Research Council's (NRC) National Science Education Standards, American Association for the Advancement of Science (AAAS) Benchmarks for Science Literacy, and other frameworks were used as guides in developing this series. The videotape presents views of real classrooms where science is being taught. Classroom situations are spontaneous and unscripted. The videotape shows how standards actually look in practice in the classroom and how teachers are guiding experiences that enable students to construct understanding and learn science processes. The guide contains information on conducting hands-on workshops including materials lists, materials sources, and handouts. The videotape focuses on the primary grades. In the first lesson, kindergarten students learn about land snails in an integrated unit that includes literature, drawing, and making models from clay and paper. In another unit, children learn about predator-prey relationships and how the structure of each living thing adapts to survive in its habitat. Finally, second grade students use prediction, number concepts, and graphing skills in their observation of the heaping property of water. (PVD)

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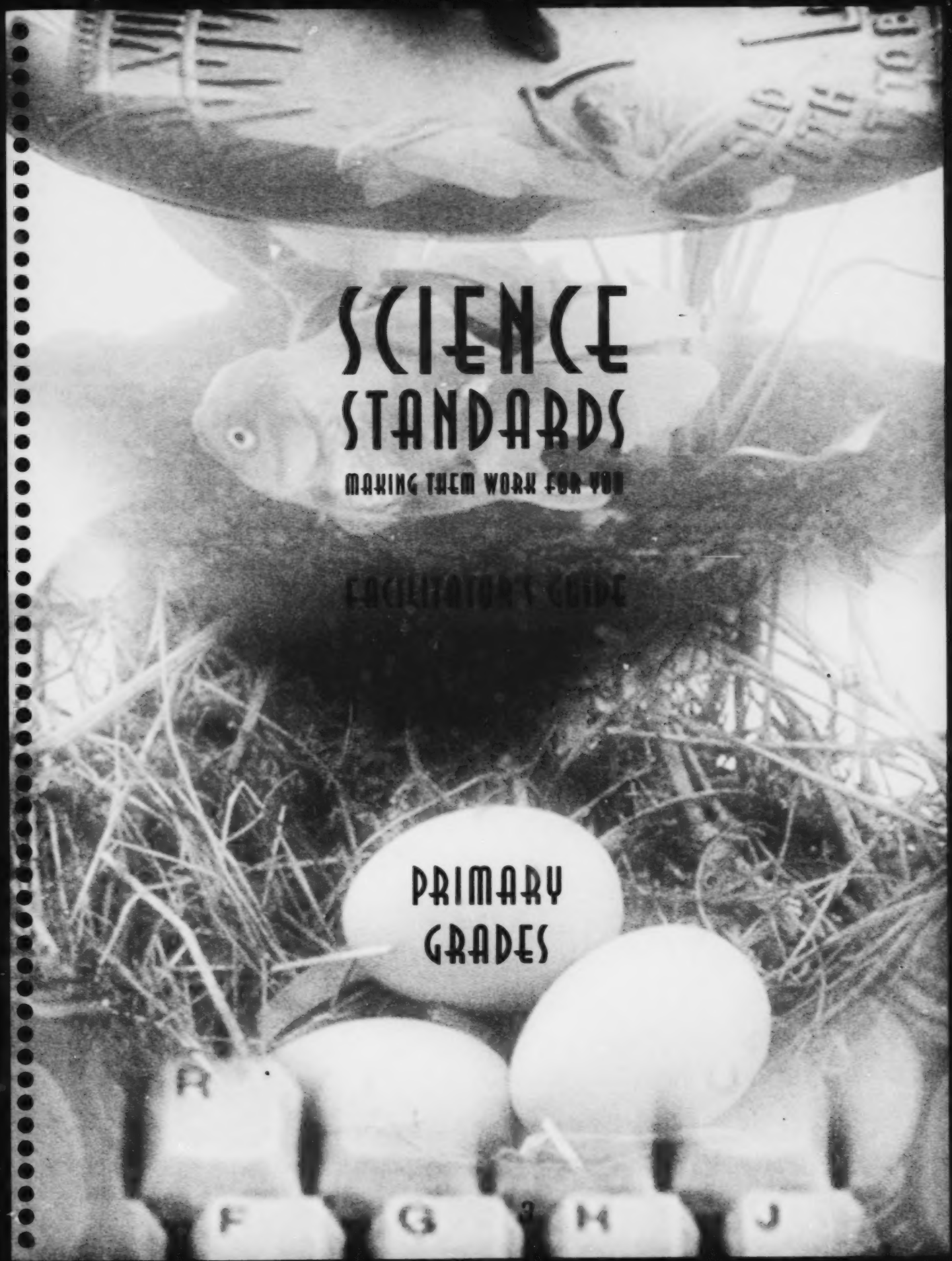
FOCUS ON SCIENCE

PRIMARY GRADES


SCIENCE
STANDARDS
MAKING THEM WORK FOR YOU
FACILITATOR'S GUIDE
PRIMARY
GRADES

About the Developers
This guide was prepared by Judy Famellette, Elementary Science Teacher, Scarsdale School District, Scarsdale, New York; Loraine Corfield Voros, co-producer/director of the videos; and John Checkley, Senior Producer, ASCD.

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ASCD Staff

Video Production
Marcia D'Arcangelo, *Manager and Executive Producer*
John Checkley, *Senior Producer*
Beth Kabele, *Project Assistant Manual Production*

Manual Production
Nancy Carter Modrak, *Manager, Editorial Services*
Carolyn R. Pool, *Associate Editor*
Gary Bloom, *Manager, Design and Production Services*
Karen Monaco, *Senior Designer*
Tracey A. Smith, *Production Coordinator*
Valerie Sprague, *Desktop Specialist*

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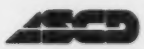

Association for Supervision and Curriculum Development
Telephone: (703) 549-9110 or 1-800-933-2723
Fax: (703) 299-8631
Internet access: gopher.ascd.org, http://www.ascd.org, or e-mail to info@ascd.org

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Science Standards: Making Them Work for You

Primary Grades

Facilitator's Guide

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INTRODUCTION

21st Century Science

By the time today's elementary school students graduate from high school, the world will be a very different place. Recent advances in science and technology have already caused dramatic changes in our way of life, and it's only the beginning. To prepare students for the challenges of the 21st century, scientists, educators, and other community members are formulating a new vision of science education, starting in the earliest grades. They are meeting to discuss what it means to be scientifically literate and what steps we need to take to help students achieve that literacy.

This new vision is reflected in several recent documents. *Benchmarks for Science Literacy* (American Association for the Advancement of Science, AAAS, 1993) details how students should progress toward the goal of science literacy described in *Science for All Americans* (Rutherford and Ahlgren 1990). *Benchmarks* lists the concepts that children should know by grades 2, 5, 8, and 12, in areas such as the "Living Environment," the "Physical Setting," and the "Nature of Technology." In *National Science Education Standards*, the National Research Council (NRC 1994—draft version) supports the goal of science literacy by giving standards not only for content and skills, but also for teaching science, teachers' professional development, assessment, and the entire science program and the system that provides it. The basic ideas of the AAAS *Benchmarks* and the NRC *Standards* are also found in *Frameworks for Curriculum and Instruction*, published by the National Center for Improving Science Education (1989), and in frameworks written by some states, such as California and New York.

These documents have a common goal: to produce a vision of science education that will guide reform and that will have an impact on curriculums and classrooms in the United States—and, indeed, in many other countries. It is the goal of this videotape series to show how that vision may be translated into classroom practice.

Assumptions

1. All children can learn science.

In fact, all children *must* learn science to live in an age of technology, where unprecedented amounts of information are available through computer networks. Science is not just for children of a particular gender, ethnicity, or socioeconomic class, nor is it just for future doctors, engineers and scientists, but for all students who will be facing the challenges of life in the 21st century.

2. ***Through their experiences, children (and adults) construct their own understanding of science and the world around them.***

As we grow, we constantly synthesize new information and experiences into what we already know. In this way, we make sense of our world. The study of science offers a wealth of opportunities for children to experience "discrepant events," which challenge them to search for new explanations and understandings.

3. ***Science content should be appropriate for the grade level taught.***

Activities and discussion should be designed to help children construct their own understanding of scientific concepts. Concepts should spiral through the curriculum, concentrating on thorough treatment of overarching ideas, rather than trying to "cover" a great deal of subject matter. ("Less is more.")

4. ***Children need experiences in the processes of science.***

Schools should use inquiry-oriented, hands-on, problem-solving techniques; and these strategies must replace traditional textbooks and worksheets. Like content, skills must also be appropriate for the child's developmental level, starting with basic skills such as observation, and progressing to the design of scientific experiments.

5. ***Science education should foster a positive attitude toward science.***

Teachers should be aware of the role of science studies in nurturing attitudes such as concern for the environment, understanding of what a scientist does, the value of scientific thinking, and an openness toward further learning.

6. ***Science education should start in the earliest grades.***

Children come to school with a natural curiosity about the world around them. Their curiosity and interest in science often disappears before they reach high school age. Teachers can capitalize on children's enthusiasm and use it to motivate learning, not just in science, but in other areas of the curriculum as well.

7. ***Children should learn the practical applications of science principles in the world.***

Technology, the science that deals with practical applications, is gaining momentum in the schools. Design projects and inventions help students to see the value of science in solving problems. Students also need to be aware of the adverse effects of technology and the difficult choices that must be made on a national level to use technology responsibly.

Purpose of the Program

This video program series, *Science Standards: Making Them Work for You*, and the *Facilitator's Guides* are designed for administrators, teachers, parents, school board members, corporate and community leaders, and all others who are interested in improving science education at the elementary school level. We have used the NRC *Standards*, AAAS *Benchmarks*, and various frameworks as guides. The videotapes present views of science classrooms, highlighting practices that illustrate recently written science standards. The *Facilitator's Guides* contain information on conducting hands-on workshops, including lists of materials, sources of materials, and handouts.

About the Program

Teaching science presents unique problems for the elementary school teacher, problems related to classroom management, questioning techniques, and assessment of hands-on learning, to name just a few. Unfortunately, constraints of time, money, and scheduling usually prevent the one thing that would help teachers the most—observing fellow teachers at work. The videos in this series show nine classrooms where science is being taught. The classroom situations are spontaneous and unscripted. These are real classrooms representing a cross-section of the New York metropolitan area, from inner city to suburbia. We hope that these videos will enable teachers to see how standards actually look in classroom practice, and how teachers are guiding experiences that enable children to construct understanding and learn the processes of science.

This video-based staff development program consists of three 30-minute videotapes and *Facilitator's Guides*. Each videotape shows the lessons of three teachers, highlighting by "video footnotes" the practices that illustrate science standards. Tape 1 focuses on the primary grades (K–2), Tape 2 on grades 3–4, and Tape 3 on grades 5–6. All teachers should have an awareness of the concepts and skills leading up to the grades they teach, as well as the concepts and skills for which their teaching forms a foundation. Therefore, we recommend that participants view and discuss all the tapes to get an idea of the developmental flow of scientific concepts and skills, as well as an overview of issues such as curricular integration, authentic assessment, cooperative learning, and constructivism.

Program Objectives

At the end of this program, participants will be able to:

- Explain the significance of documents such as the NRC *Standards*, AAAS *Benchmarks*, and various frameworks.
- Design at least one science lesson that demonstrates effective management of materials, questioning techniques, integration, and authentic assessment.
- Describe the role that elementary science plays in preparing students for life in a technological information age.
- Recognize the motivational value of hands-on science activities.
- Identify issues and concerns involved in implementing science standards.
- Develop a personal or group plan of action related to the science standards.

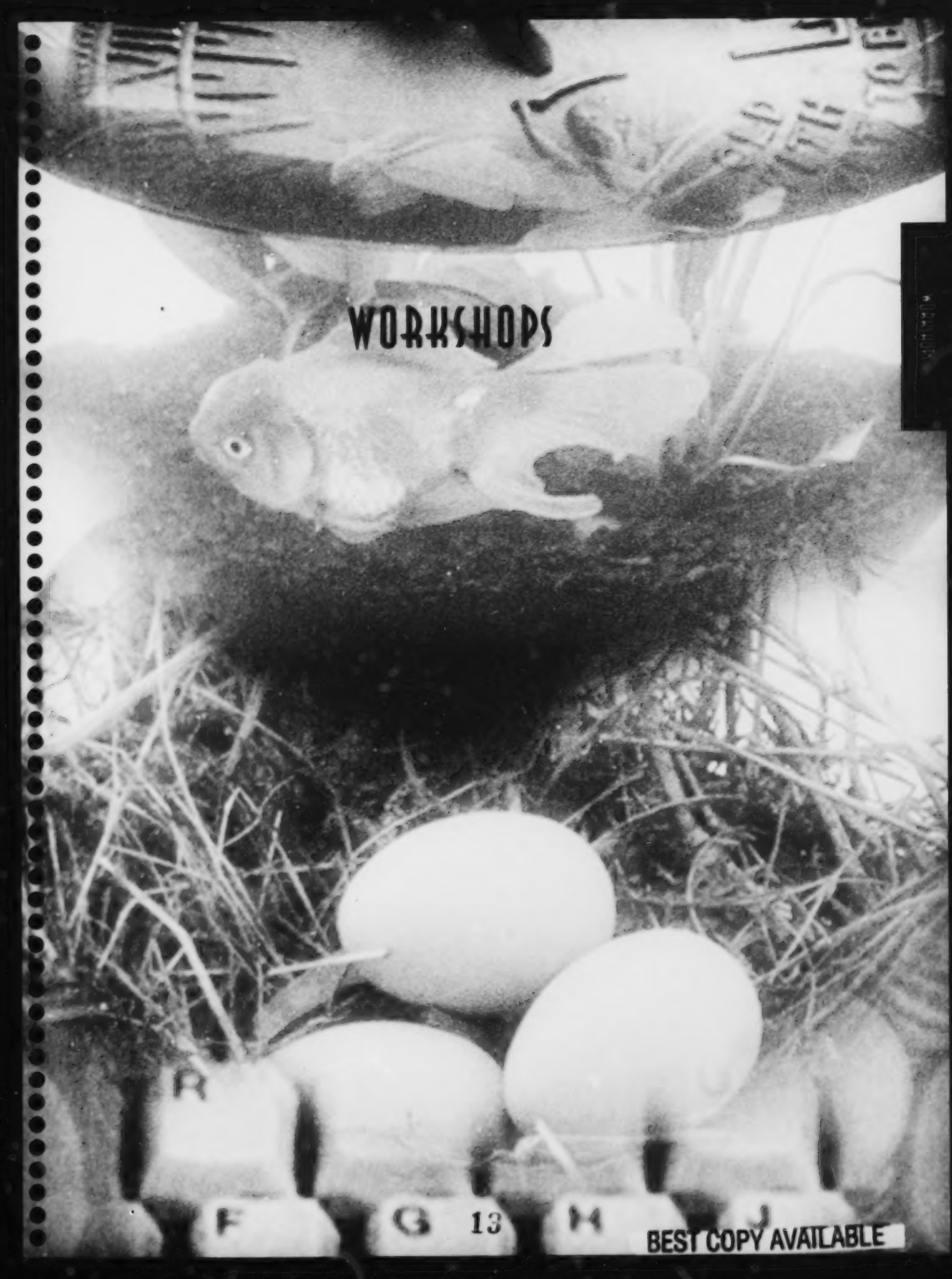
Role of the Facilitator

Whether you decide to simply show the videos to a group or conduct workshops, as facilitator of this viewing process, you could be a staff developer, principal, central office administrator, or teacher. As the facilitator, your preparation for the workshop and openness to discussion will enable you to help your group benefit from this program. Remember, you may be showing this video to a diverse group, and your background knowledge and outside reading will be beneficial. As a facilitator, your major responsibilities are as follows:

- **Read and View the Materials**
  - — Have you viewed the videotape?
  - — Have you read the *Facilitator's Guide*?
- **Prepare the Program Activities**
  - — Are you prepared to guide a group through the activities and discussions necessary in the workshops?
  - — Do you have a sound background in the concepts and process presented in the videos, or do you need to do further reading?
  - — Have you tried the hands-on activities to ensure that the presentation goes smoothly?

- **Check the Room and the Seating**
  - — Have you reserved a room that is large enough, with ample seating and tables for hands-on activities? (Tables for groups of 4 work best, to model cooperative grouping.)
  - — Is the room conducive to a follow-up group discussion?
- **Arrange for a Working VCR and Monitor, and Ensure Proper Electrical Fittings**
  - — Have you arranged for the use of a VCR and monitor? (One 23–25-inch monitor will suffice for up to 25 participants.)
  - — Have you tested both machines to ensure that they are in working condition?
  - — Are the electrical outlets in the room in working order?
  - — Do you have power cords with adapters that will allow you to use the VCR?
- **Prepare Materials**
  - — Have you gathered the necessary materials for the hands-on workshops, and arranged them in trays or bags to facilitate distribution, and to model an appropriate classroom management procedure?
  - — Have you tried the activities, to see if they work for you?
  - — Have you duplicated enough handouts for all participants?
  - — Are there any supplementary articles you would like to give as handouts? (See "References and Resources" section.)
  - — Have you prepared transparencies from the "Overheads" section of this guide?
  - — Have you duplicated overheads, if necessary?
  - — Do you have extra, blank transparencies available?
- **Arrange for Other Equipment**
  - — Does the room have an overhead projector, a screen, and perhaps a flipchart?
  - — Do you have a sufficient supply of pens or markers for charts or transparencies?

- **Announce the Program**
  - — Have you specified clearly the day, month, time, and location for the program? (Remind participants to bring pencils and notepads.)
  - — Because of the subject matter of this program, have you specifically invited parents, community leaders, and business representatives?
- **Make Other Arrangements**
  - — Have you prepared the agenda, with times for breaks?
  - — Have you arranged for refreshments?



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Workshop 1

We suggest three viewing formats to meet the needs of diverse audiences. This workshop offers an introduction to the NRC *Science Standards*, AAAS *Benchmarks for Science Literacy*, and various science frameworks, for a group of participants who would like an overview of the topic, and a look at how these documents apply to classroom practice. This format would be ideal for an evening community-school meeting, a school board presentation, or a parent-teacher forum. It will be effective for an audience that includes parents, teachers, administrators, and community representatives.

We suggest the following agenda for this 70-minute session.

Agenda and Time Guide: Workshop 1

Activity	Time (minutes)
Welcome and Introductions	5–10
Video Viewing	30
Making Science Standards Work for You (Primary Grades)	
Reflections	20
Approximate Workshop Time	70 minutes

Facilitator's Note

Whenever appropriate, refer to the quotes from the NRC Standards, AAAS Benchmarks, and various science frameworks, printed in the margin.

Workshop Materials

For this workshop, you will need copies of Handouts 1 and 2 for all participants, as well as a flipchart or chalkboard and appropriate markers. If this is a large group, an overhead projector with blank transparencies might be more effective as a way to make notes that everyone can see. If you think participants would be interested, you might distribute one or more of the readings from the "References and Resources" section.

Welcome and Introductions (5–10 minutes)

1. Welcome all participants. Introduce yourself and explain your role as workshop facilitator. As the facilitator, you will guide the group through the workshop activities to help them address the following questions (place relevant questions on flipchart/overhead transparency):

   - What are the implications of science standards in our school (or district)?

- How is our school (or district) responding to the need for better science education?
- What kind of commitment is involved in meeting the standards for science education, in terms of resources, support, and staff development?
- What part(s) of the video interested you most?
- What questions would you like to ask the teachers depicted in the video?
- Do you think this video should be shared with a wider audience in our school, district, and community? Why?
- What activities have you seen or done that illustrate the science standards?

2. Depending on the size of the group and whether the participants know each other, you may want to set aside time for participants to introduce themselves individually.

3. Distribute Handout 1, "Self-Assessment." After participants review the handout, ask them to state why they are interested in learning about science standards and to describe briefly the extent to which they are familiar with standards. Explain that they will not be turning the handout in; but they may wish to share their thoughts later in the workshop.

Video-Viewing Activities (35 minutes)

1. Call participants' attention to the list of questions from your flipchart or overhead transparency.

2. Ask participants to consider, while watching the program, the effect science standards have on all students and on the roles of staff members in the featured schools. Also ask them to consider what it would take to implement the standards in their curriculum.

3. View the video (30 minutes).

Reflections (20 minutes)

1. Distribute Handout 2, "Reactions to Video," and allow participants 10 minutes to record their reactions.

2. Invite participants to engage in a discussion, based on their reactions to the video. Record their reactions on a chalkboard or flipchart.

3. After the discussion, ask participants to share their answers to the original list of questions.

4. Close the workshop by reviewing some of the key points mentioned during the discussion, and address any questions the participants may have about additional workshops.

Workshop 2

We suggest holding this half-day workshop for those who are familiar with the content and process of elementary science education, but wish to explore and discuss issues such as integration, assessment, classroom management, and construction of scientific concepts. This program, *Science Standards: Making Them Work for You (Primary Grades)*, is intended primarily for educators, parents, community members, businesspeople, and others interested in what recently written science standards have to say about science education for the primary grades. The times listed here include the time required for viewing the video and suggested times for completing the follow-up activities. You may wish to allow additional time for group discussion.

Agenda and Time Guide: Workshop 2

Activity	Time (minutes)
Introductory (Warm-Up) Activity	25
Workshop Activity—Pennies in Water	30
View Video	30
Science Standards: Making Them Work for You (Primary Grades)	
Break	15
Follow-up Activities	60
Concluding Activity	15
Approximate Total Workshop Time	3 hours

Workshop Materials

For this workshop, you will need, for each participant (listed in the order you will need them), copies of:

- Handout 1
- The entire "Lessons" section of the guide. (Optional—use this for audiences that need detailed instructions and background materials.)
- Handout 2
- Any readings in the "References and Resources" section that you feel are appropriate.

You will also need to make a transparency of Overhead 1, from the "Overheads" section. (We also suggest using any of the quotations in the margins of this manual as overhead transparencies.)

You will also need the following materials:

- A clear glass or plastic cup
- Water
- At least one pad of Post-It™ notes
- About a dollar's worth of pennies for demonstration purposes, more if you want participants to do the activity at their own tables, about 50–75 cents' worth for each group.
- Paper towel (one roll should be enough)
- A large chart, similar to the one shown in the last segment of the video, for participants to record predictions, using the Post-It notes™. (See model, at the back of the Lessons section.)
- Tape for posting the chart

Introductory (Warm-up) Activity (25 minutes)

1. Write the workshop objectives on the overhead, flipchart or board before the participants arrive.
2. At the door, have a sign-in sheet for participants to record their names, addresses, and phone numbers.
3. Also at the door, set up the materials for the Pennies in Water lesson, which will immediately engage participants in one of the activities shown in the video (see the preceding list, "Workshop Materials"). The recording chart, which follows, also gives instructions for the lesson.

4. As the participants sign in, give each person a Post-It™ note, and direct them to the table where the cup of water and recording chart are located. Ask each person to write his or her name on the note, estimate the number of pennies that can be added to the cup before the water spills, and place the Post-It™ note on the chart, within the range that includes his or her prediction.

Recording Chart

How many pennies can we put in the cup before the water spills? Write your prediction on a Post-It Note and place it on this chart, within the range of your prediction:

0–5	6–10	11–15	16–20	21–25	26–30	More than 30

5. Introduce yourself to the participants. In addition to telling your name and what you do, write your name on a flipchart or on the board. Explain your role as the workshop facilitator. As a facilitator, you will guide the group through the workshop; you will help them meet the workshop goals. Call their attention to the goals on the overhead, flipchart, or board (if you wish, show Overhead 1, "Objectives of the Workshop"). Briefly discuss these objectives.

6. Tell participants the following:

   - **In this activity, we will focus on what we want to accomplish in this workshop, what we think the NRC *Science Standards*, AAAS *Benchmarks for Science Literacy*, and various science frameworks mean to classroom practice, and why we may want to change our approach to teaching science.**

7. Distribute Handout 1, "Self-Assessment." Explain the purpose of the activity by giving the following instructions:

   - **All of us have a common goal—to improve education so our children are prepared to meet the demands of our technological society. What we may not agree on is how we proceed to achieve this goal. By completing this self-assessment handout, we can start the workshop with a better understanding of our feeling about the role of science in elementary education, and the implications of science standards, benchmarks, and frameworks.**

Allow participants about 5 minutes to complete the form.

8. Ask participants to share their answers with others (groups of three or four).

9. Ask the groups to report their answers to questions 1 and 2. If time allows, record the answers on the flipchart or a transparency.

Workshop Activity—Pennies in Water (30 minutes)

1. After participants have had a chance to discuss the self-assessment, introduce the first workshop activity by directing the group's attention to the cup of water and pennies. Ask them how many pennies they think can be added to the cup of water before the water spills. Ask for reasons for their predictions.

2. Direct their attention to the chart on which they recorded their predictions, using the Post-It™ notes. Explain that the activity is a preview of one of the lessons shown in the videotape. Discuss the predictions on the graph, asking questions such as:

   - What was the range of the most common prediction?
   - Were the predictions generally above or below 25?
   - What range, if any, was not picked?
   - How does the graph help to organize information about the group's predictions?

3. After participants have had the opportunity to discuss the graph and the reasons for their predictions, ask for a volunteer to test the predictions, gently placing the pennies one by one sideways into the water, and counting them. (If possible, you may want to have a cup of water and pennies at each table, and have the members of the group take turns adding the pennies.) As the numbers get higher, some people may want to change their predictions, based on their observations.

4. Ask participants for general comments on the activity.

   - What did you learn?
   - What do you think children can learn, in terms of science? In terms of math?
   - If you were to do this activity again, how would the graph look?

Viewing the Videotape (30 minutes)

1. Introduce the videotape by telling the participants:

   - **Recent concern about the status of U.S. science education has stimulated the creation of a number of documents that describe standards for science education. Documents like the National Science Standards, and the Benchmarks for Science Literacy outline what students need to know and do in order to be scientifically literate. The video we're about to see:**

     - **introduces examples of some of the science standards,**
     - **presents examples of classrooms where standards are being implemented, and**
     - **shows what the standards actually look like in classroom practice.**

2. Before playing the video, say to participants:

   - **As you watch the program, consider what each teacher is doing and think about whether it should and could work in your school or class. What adaptations, if any, could you make for your class?**

3. Answer any simple and direct questions. Then view the entire videotape (30 minutes).

Break (15 minutes)

A break following the video will give the audience a chance to discuss informally what they have seen and heard so far. They can begin to internalize and organize their thoughts for the remainder of the workshop.

Follow-up Activities (60 minutes)

The following are questions that you may ask participants after viewing the video:

- What is your general reaction to the activities and issues shown in the videotape?
- What special considerations need to be addressed by the teacher, in using the NRC *Standards*, the AAAS *Benchmarks*, and the frameworks as guides to science education?

- What kind of district and administrative support is necessary for a teacher to use the standards, benchmarks, and frameworks as guides to science education?
- How do the activities shown in the video compare with those in your school?
- How do the assessment methods shown in the video compare with those in your school?
- What evidence did you see that science was integrated with other areas, such as math, literature, art, social studies?
- What kinds of classroom management techniques were shown?
- What concerns do you have about the implications of the NRC *Standards* and AAAS *Benchmarks* to elementary science education?

Concluding Activity (15 minutes)

1. Distribute Handout 2, "Reactions to Video," and explain the following to participants:

   - **In a few minutes, I'm going to ask for volunteers to begin forming an elementary science planning team to consider the issues raised in this workshop and suggest possible strategies with which to address them. To help you in this task, you will have the notes I've taken on the discussion, and the summaries written by the recorder in each group. At a future meeting, the team will present suggestions on possible efforts to use science standards to institute change in our science program.**

2. After participants have had sufficient time to write their responses, collect the handout.
3. Ask volunteers to sign up on the sheet you will distribute, if they are interested in being a member of a planning/leadership team.
4. Set a meeting time in the next couple of weeks for the team to meet.

Workshop 3

This full-day workshop is suggested for beginning teachers and others who are unfamiliar with the content and process of elementary science education, and wish to explore and discuss issues such as integration, assessment, classroom management, and construction of scientific concepts, within the context of actual classroom situations. This program, *Science Standards: Making Them Work for You (Primary Grades)*, is intended primarily for educators, parents, community members, businesspeople, and others interested in what recently written science standards have to say about science education for the primary grades. The times listed here include the time required for viewing the video and suggested times for completing the hands-on and follow-up activities. You may want to adapt this schedule by showing the video in three 10-minute segments, followed by the appropriate activities, or by conducting the activities first, then showing the video.

Agenda and Time Guide: Workshop 3

Activity	Time (minutes)
Introductory (Warm-Up) Activity	30
Hands-on Workshop—Pennies in Water	45
View Video	30
Science Standards: Making Them Work for You (Primary Grades)	
Break	15
Hands-on Workshop—Animal Defenses	45
Lunch Break	60
Hands-on Workshop—Snail Study	45
Follow-Up Activities	30
Small-Group Planning, by Grade Level	30
Sharing and Concluding Activity	30
Approximate Total Workshop Time	(5 hours)

Workshop Materials

For this workshop, you will need, for each participant (listed in the order you will need them), copies of:

- Handout 1
- Handout 2

- Handout 3
- The entire "Lessons" section of the guide
- Any readings in the "References and Resources" Section that you feel are appropriate.

You will also need to make a transparency of Overhead 1, from the "Overheads" section. We also suggest making transparencies of any of the quotations (enlarged) in the margins of this manual.

Set up the following materials, arranged for ease of distribution:

For the Pennies in Water Activity

- A copy or transparency of Overhead 1
- A wide-mouthed glass or plastic cup
- Extra cups or glasses—allow two for each group, one to hold the water, the other for carefully pouring to the top
- Water
- At least one pad of Post-It™ notes
- Pennies—about a dollar's worth for demonstration purposes, plus about 50-75 pennies, in plastic bags, for each group.
- Paper towel (one roll should be enough for the whole group)
- A large chart, similar to the one shown in the last segment of the video, for participants to record predictions, using the Post-It™ notes. (See model at the back of the Lessons section.)
- Medicine droppers (optional—for extension activities)

For the Animal Defenses Activity

Set up the following materials on the demonstration table, near the overhead projector (for cutout patterns, see Lessons section):

- Tyrannosaurus rex cutout
- Defenseless Denny cutout
- Cutout paper "ferns"
- Plastic overlays for drama—mountain, sky, and moon
- Construction paper

- Scissors
- Glue
- Overhead projector
- Animal models, or stuffed animals

For Each Group of Participants, a Basket, Box, or Tray, Containing:

- Construction paper—different colors and scraps
- Scissors (one per participant)
- Glue (can be shared, but one per participant is better)
- Cutout "Defenseless Dennys" (one per participant)

For the Triorama

- Model of triorama (optional)
- Large construction paper sheets, about 11" × 17" or 11" × 11" squares

For the Snail Study

- Land snails—these can often be purchased from fish markets, or collected in the wild in some areas. (Gardeners will thank you for removing them.) They can also be ordered from Connecticut Valley Biological Supply, 82 South Valley Road, P.O. Box 326, Southampton, MA 01073, or phone 1-800-628-7748. (Their catalog # 35A is the largest and easiest to observe.) Some fish markets also sell snails, but it is important to get land snails, and not the ocean variety.
- Petri dishes (optional)
- Medicine droppers, dropping bottles, or spray bottles with water
- Magnifiers
- Carrots (or lettuce, or various other vegetables)
- Chalk
- Habitat—a small aquarium, large jar, or other container, with about 5 cm (2 inches) of soil in the bottom (see description in Lessons section)
- Model of paper snail (optional)

- A copy of the book, *The Snail's Spell*, by Joanne Ryder

Introductory (Warm-up) Activity (30 minutes)

This activity introduces members of the group to one another, and to one of the activities shown in the videotape.

1. At the door, have a sign-in sheet for participants to record their names, addresses, and phone numbers.

2. Also at the door, set up the Pennies in Water materials (see the preceding list, "Workshop Materials"), which will immediately engage participants in one of the activities shown in the video.

3. As the participants sign in, give each person a Post-It™ note, and direct them to the table where the cup of water, instruction sheet, and recording chart are located. Ask each person to write his or her name on the note, estimate the number of pennies that can be added to the cup before the water spills, and place the Post-It™ note on the chart, within the range that includes his or her prediction. The recording chart, which follows, also gives instructions for the lesson.

Recording Chart

How many pennies can we put in the cup before the water spills? Write your prediction on a Post-It Note and place it on this chart, within the range of your prediction:

0–5	6–10	11–15	16–20	21–25	26–30	More than 30

4. Introduce yourself to the participants. In addition to telling your name and what you do, write your name on a flipchart or on the board. Explain your role as the workshop facilitator. As a facilitator, you will guide the group through the workshop; you will help them meet the workshop goals. Call their attention to the goals you have written on the flipchart or board (or show Overhead 1, "Objectives of the Workshop"). Briefly discuss these objectives.

5. Tell participants the following:

   - **In this activity, we will focus on what we want to accomplish in this workshop, what we think the NRC *Science Standards*, AAAS *Benchmarks for Science Literacy*, and various science frameworks mean to classroom practice, and why we may want to change our approach to teaching science.**

6. Distribute Handout 1, "Self-Assessment." Explain the purpose of the activity by giving the following instructions:

   - **All of us have a common goal—to improve education so our children are prepared to meet the demands of our technological society. What we may not agree on is how we proceed to achieve this goal. By completing this handout, we can start this workshop with a better understanding of our feeling about the role of science in elementary education, and the implications of the NRC *Standards*, AAAS *Benchmarks*, and various frameworks.**

7. Ask participants to form groups of three or four people and share their answers with their groups.

8. Ask the groups to report their answers to questions 1 and 2. If time allows, record the answers on the flipchart or a transparency.

Hands-on Workshop—Pennies in Water (45 minutes)

1. After participants have had a chance to discuss the self-assessment, introduce the first workshop activity by directing the group's attention to the cup of water and pennies. Ask them how many pennies they think can be added to the cup of water before the water spills. Ask for reasons for their predictions.

2. Direct their attention to the chart on which they recorded their predictions, using the Post-It™ notes. Explain that the activity is a preview of one of the lessons shown in the videotape. Discuss the predictions on the graph, asking questions such as:

   - What was the range of the most common prediction?
   - Were the predictions generally above or below 25?
   - What range, if any, was not picked?
   - How does the graph help to organize information about the group's predictions?

3. After participants have had the opportunity to discuss the graph and the reasons for their predictions, ask for one person from each group to come to the supply area to get two cups, each a little over half-full with water. Have another volunteer pick up the pennies and a paper towel or two. Instruct them to place the paper towel on the table, with one cup of water on it, and, with the eyes at cup level, carefully add water from the second cup until the level of the water is exactly even with the top of the cup. Then have them test the predictions, taking turns gently placing the pennies one by one sideways into the water, and counting them. As the numbers get higher, some people may want to change their predictions, based on their observations.

4. Ask participants for general comments on the activity. Throughout the workshop, asking questions that begin with "Why do you think . . . ?" and "How do you know . . . ?" will help you model the kind of questioning techniques that encourage others to share and clarify their thoughts by putting them into words.

   - Were you surprised by the results?
   - Why (not)?
   - What did you observe during the activity?
   - Why DO YOU THINK that happened? The point here, as in the classroom, is not to get the "correct" answer, but to listen to what participants think. Therefore, all answers that describe their thinking are correct.
   - Were there any differences in the results obtained by the different groups?
   - Why do you think the results may have been different?
   - How do you think a primary-age child would respond to these questions?

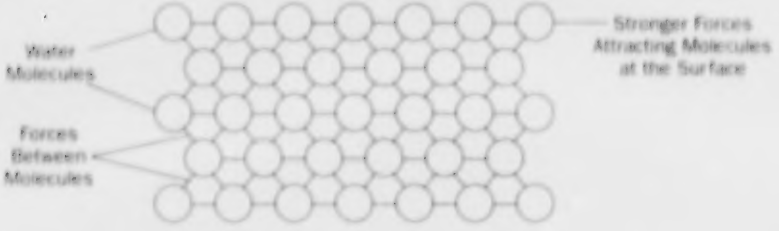
5. Clean-up—Assign one person from each table to dump the water into a sink or large container, organize the materials, and put them back where they got them.

6. Distribute the Lessons. Call the participants' attention to the scientific background material for the "Pennies in Water" section contained in page 47 of the Lessons section. Read it with them, as follows:

- **Surface tension acts like an invisible film on the surface of water or any other liquid. The surface tension of water is strong enough to support water that rises a short distance above the top of a container, enabling the water to "heap."**

  Surface tension is caused by the natural attraction that occurs among molecules. In any container of water, all of the molecules attract one another in all directions with a particular force. The molecules at the surface, however, have a stronger attraction for one another, because there are no water molecules above them to attract.

Diagram of Water Molecules



With participants, discuss the following questions:

- Should this information be shared with children of primary age? (The abstract nature of this material is not appropriate for most children of this age.)
- Is it appropriate for the teacher to know this background information, as a way of understanding the role of this activity in the construction of the child's understanding, or to increase the teacher's own scientific literacy?
- How can this activity help the child to "accumulate a set of concrete experiences on which they can draw," as mentioned in the AAAS *Benchmarks*? Extension activities included in the packet can provide further experiences in this area.

Viewing the Videotape (30 minutes)

1. Introduce the videotape by telling the participants:

   - **Recent concern about the status of U.S. science education has stimulated the creation of several documents that describe standards for science education. Documents like the NRC *National Science Education Standards*, the AAAS *Benchmarks for Science Literacy*, and various sets of science frameworks outline what students need to know and do to be scientifically literate. The video we're about to see:**

     - **introduces examples of some of the science standards,**
     - **presents examples of classrooms where standards are being implemented, and**
     - **shows what the standards actually look like in classroom practice.**

2. Before showing the video, say to participants:

   - **As you watch the program, consider what each teacher is doing and think about whether it should and could work in your school or class. What adaptations, if any, could you make for your class?**

3. Answer any simple and direct questions. Then view the entire videotape.

Break (15 minutes)

A break following the video will give the audience a chance to informally discuss what they have seen and heard so far. They can begin to internalize and organize their thoughts for the remainder of the workshop.

The break will also give you time to check the materials for the next workshop. Have them arranged to facilitate distribution, and to model a classroom management technique. For instance, if you have four people at each table, prepare a basket, box, or pan for each table, with construction paper scraps and four each of scissors, glue, and "Defenseless Denny" cutouts. You may also want to prepare models of the triorama, described on pages 51 and 52 of the Lessons section—or, if time permits, large sheets of construction paper for participants to make their own trioramas.

Hands-on Workshop—Animal Defenses (45 minutes)

1. Introduce the activity by giving the following instructions:

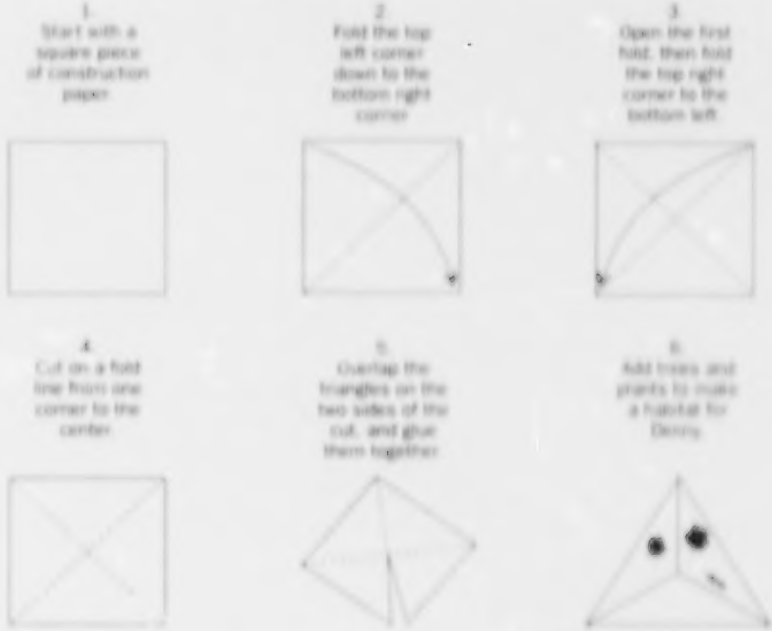
   - **You have already participated in one of the activities shown on the videotape. Science activities involve a special kind of planning and classroom management, and so it is important for the teacher to have this kind of practice before introducing a lesson to the class. You're going to have a chance to experience some parts of the lessons shown in the video, from a student's point of view. As you participate in the lesson, put yourself in the child's place, and try to think of how the lesson contributes to the development of scientific concepts, skills, and attitudes.**

   Then, model the Animal Defenses lesson (see the preceding list, "Workshop Materials").

2. The following objective is the focus of the lesson:

   Objective: Students will make models that illustrate how the structure of an animal can protect it from predators.

Making A Triorama


1.
Start with a square piece of construction paper
2.
Fold the top left corner down to the bottom right corner
3.
Open the first fold, then fold the top right corner to the bottom left
4.
Cut on a fold line from one corner to the center
5.
Overlap the triangles on the two sides of the cut, and glue them together
6.
Add trees and plants to make a habitat for Denny.

3. Using models, pictures, and stuffed animals, discuss the many ways that animals' structures and behaviors protect them from predators and the elements. Many dinosaurs were protected by teeth, claws, plates, spikes, and long tails. Examples of modern-day defenses from predators include a cat's teeth and claws, a skunk's odor, a turtle's shell, a deer's long legs, and a rabbit's protective coloration. The polar bear's fur and a bird's feathers protect them from cold. Desert creatures protect themselves from heat by staying underground during the day and coming out at night.

4. Make up a drama of a defenseless animal, using the cutouts of the Tyrannosaurus rex, the defenseless animal, and paper ferns (see Lessons section). Tell the participants that they are going to see a story about a make-believe animal that lived in the time of the dinosaurs. Show them the cutouts of the defenseless animal, the Tyrannosaurus rex, and the ferns at appropriate times during the story. The script might go something like this:

   - **This is a story of an animal that lived in the time of the dinosaurs. It has no teeth, no claws, no tail, no plates, nothing to protect it from the fierce Tyrannosaurus rex. Tyrannosaurus rex is looking for something to eat, so the defenseless animal has to hide in the ferns. She's hungry too, but she can't come out, for fear of T. rex. What can we do to protect this poor animal, so she can come out and get something to eat?**

5. Follow suggestions from the participants about defenses to add, cutting claws, teeth, and other defenses from paper and glue them on.

6. Put the animal back in the ferns. Have T. rex return. Now the animal can go out of the ferns when she's hungry, to look for food, because she has defenses.

7. Tell participants that they will have their own defenseless animal cutout to "protect."

8. Distribute the cutouts, paper, glue, and scissors, and allow participants to construct defenses for the animal.

9. Continue the story, using the overhead projector. Use overlays of the mountain, sky, and sun for background. Have the Tyrannosaurus rex "walk" across the screen, describing the action:

   - **Here's Tyrannosaurus rex. He's out looking for food again. Out in the distance, he sees some animals. Will he be able to eat them?**

10. Ask for volunteers to use the overhead projector to describe their animal's defenses.

11. Ask participants for comments. How does the activity contribute to the child's study of animals and to the development of process skills and attitudes? How does it illustrate principles expressed in the standards?

12. If time permits, show the model of the triorama, and allow participants to make their own models.

Lunch Break (60 minutes)

Hands-on Workshop—Snail Study (45 minutes)

1. Ensure your workshop materials are arranged for easy access.

2. Introduce the activity by giving the following instructions:

   - **In the video, the Animal Defenses activity helped children construct understanding of the relationship between the structure of an animal and its function. Next, we'll have the opportunity to see how this principle relates to a real animal. The land snail, shown in the video, is a good animal for classroom study. It is relatively easy to care for, it can't hurt children, and it is highly unlikely that children will be allergic to it.**

3. The following objective is the focus of the lesson:

   Objective: The student will observe and describe the properties and habits of a living creature, the land snail.

4. Discuss with participants what they already know about snails. They may be familiar with ocean or fresh water snails. Make sure they know that the snails they will observe are *land* snails, which would drown if submerged in water. Try not to comment on the rightness or wrongness of their statements. It may be more appropriate to ask questions such as, "What do you think?" or "How do you know . . . ?" You may want to write down their statements, or to model the K–W–L format: What We KNOW, What We WANT to Know, and later, What We LEARNED.

5. Discuss the care and treatment of living things, emphasizing their small size, compared to humans.

6. Distribute the petri dishes and snails for participants to observe. It may be necessary to place a few drops of water inside the shell to wake the snail up. (If snails have been sleeping for a long time, it's a good idea to spray them with water about a half-hour before the lesson, to wake them up.)

7. In small groups, encourage the participants to observe the snails and their behavior. Suggested questions:

   - What are those things on the snail's head?
   - Are they all the same?
   - What are they used for? What makes you think so?
   - What happens when you touch them (the antennas)?
   - What happens if you turn the dish upside down? Will the snail stick?
   - Looking through the transparent petri dish, what can you observe about the way the snail moves?
   - Looking through the petri dish, can you see a dark area near the front? What do you think it is? Why?
   - Is your snail a tightrope walker? Can it walk on your pencil?

8. Distribute magnifying glasses for a closer look. If the magnifier has two lenses, the smaller one with the greater curvature will magnify more.

9. Distribute carrot sticks to feed the snails. If the snail is hungry, it will make a visible depression in the carrot in a few minutes. You may want to offer the snail different types of food to determine preferences.

10. After participants have observed the snails, collect them and return them to their habitat. Gather participants together and discuss their observations.

Follow-up Activities (30 minutes)

1. Say to participants:

   - **Here are some questions that you may be asking after viewing the video and participating in the activities. Let's discuss them, and I'll jot down some of your comments.**

2. The following are questions that you may ask the participants:

   - What is your general reaction to the activities and issues you have seen and experienced?
   - What special considerations need to be addressed by the teacher in using science standards as guides to science education?
   - What kind of district and administrative support is necessary for a teacher to use the science standards as guides to science education?
   - How do the activities compare with those in your school?
   - How do the assessment methods shown in the video compare with those in your school?
   - What evidence did you see that science was integrated with other areas, such as math, literature, art, social studies?
   - What kinds of classroom management techniques were shown?
   - What techniques did teachers use to hold the attention of the class?
   - What concerns do you have about the implications of science standards to elementary science education?

Small-Group Planning, by Grade Level (30 minutes)

1. Ask the participants to form small groups, by grade level. Distribute Handout 3, "Small-Group Discussion/Planning."

2. Instruct participants to use the handout as an outline for their group's discussion, and appoint a spokesperson to record responses and report to the entire group.

Sharing and Concluding Activity (30 minutes)

1. After participants have had sufficient time to write their responses to Handout 3, invite the spokespersons to share their responses.

2. Ask volunteers to sign up on the sheet you will distribute, if they are interested in being a member of a planning/leadership team.

3. Set a meeting time in the next couple of weeks for the team to meet.

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HANDOUT 1

Self-Assessment

Answer these questions as well as you can. Be as specific as possible. You'll share your answers with others in the workshop. Use separate sheets of paper, if necessary.

1. I am concerned about elementary science education because:

2. If I were writing standards for science education in the elementary grades, the most important issues I would want to address are:

3. How would science standards improve my effectiveness as a teacher?

4. How would use of the science standards as a guide improve my students' performance?

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HANDOUT 2

Reactions to Video

Use this handout to record your reactions to the program.

1. My initial reaction to the video is:

2. The benefits that I see happening through science standards:

3. The schools on the tape have the following characteristics in common with my school:

4. The schools on the tape differ from my school in the following ways:

5. Characteristics that I did not see on the tape that I would like to be present at my school are:

6. I can help my school improve the science program by:

7. I am still very concerned about:

8. I would like to know more about:

9. In the area of science education, my school can be proud of:

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HANDOUT 3

Small-Group Discussion/ Planning

Appoint a spokesperson to record and report for the group and use the following questions as an framework for your discussion:

As a result of this session:

1. Three important things I've learned are:

2. Two ideas or insights I would like to share with colleagues back home are:

3. One action I will take immediately is:

4. I would like to know more about:

5. I need:

6. I can get what I need by:

7. I can make a difference in my district/school/grade/class by:

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The videotape series shows sample lessons that illustrate what science standards actually look like in classroom practice. For teachers and anyone who wants more information on the lessons depicted, this packet contains lesson plans, background information, suggestions for integration, and other materials. The lessons need to be studied in the context of the total curriculum. They are in no way intended to represent a complete curriculum.

Pennies in Water

Students should be doing things, especially in science, that require them to pose questions that can be answered only by numbers associated with things.
AAAS Benchmarks for Science Literacy

Overview

In this 2nd grade class shown in the video, Maria Pages engages her students in a problem-solving activity that uses prediction, number concepts and graphing skills to focus on the observation of the "heaping" property of water. Students predict how many pennies can be added to a cup that is already filled to the brim with water, and record their predictions on a graph. When the count goes higher than expected, students are allowed to revise their predictions.

Lesson Plan

Problem: How many pennies may be added to a cup of water that is already filled to the brim, before the water spills?

Objectives: Students will observe the EFFECTS of surface tension, gain experience in constructing graphs, figure which two numbers their prediction comes between, and count to large numbers.

Materials:

- ✓ a cup or glass (the wider the mouth of the cup, the more pennies it will hold before spilling)
- ✓ water
- ✓ a large chart for constructing the graph (see model at the back of this packet)
- ✓ Post-It™ notes
- ✓ pencils or markers

Procedure

1. Place a sheet of paper toweling on the demonstration desk or table. (If the table isn't level, it should be made steady by placing folded paper under the short leg.) Place the cup or glass on the paper towel

and fill it to the brim with water. When viewed from the side, the level of the water should be exactly even with the top of the cup.

2. Introduce the problem. Ask students to predict how many pennies may be added to the cup before the water spills. (Usually, predictions range between 1 and 20.)

3. Distribute colored Post-It™ notes and ask students to write their names and predictions on the notes. (Maria, the teacher in the videotape, made red borders on the first set of notes, and used blue-bordered notes for the second round of predictions.)

Recording Chart

How many pennies can we put in the cup before the water spills?

0–5	6–10	11–15	16–20	21–25	26–30	More than 30

4. Explain the graph and the process of placing the notes within the proper range on the graph.

5. Call the children to the graph in small groups to place their predictions.

6. Analyze the graph with the whole class, asking for the most common and least common predictions. Some teachers may want to discuss total number of predictions, median prediction, range, etc.

7. Start the count, placing the pennies carefully in the water to avoid splashing.

8. When the count starts to get higher than most of the predictions, ask the children if they want to change their predictions. Distribute a different color notes for the new predictions. As before, the children record their names and predictions on the notes, and place them in the appropriate ranges on the graph.

9. Analyze the graph again, noting the difference between the first and second predictions.

10. Resume counting. When the water spills, draw the children's attention to the "heaping" of the water above the surface of the cup. This is made possible by the surface tension of the water. Ask

children why they THINK the water level rose as the pennies were added.

11. Propose questions that will extend the children's understanding of science and math concepts. What would happen if dimes or nickels were used instead of pennies? How much money, in dollars and cents, would be needed to replace the pennies with nickels? With dimes?

By the end of second grade students should be able to describe and compare things in terms of numbers.
AAAS Benchmarks for Science Literacy

12. Allow children to repeat the activity at the science center, either with pennies or, if possible, with nickels or dimes. Allow them to carry out some of the investigations in the "Extension Activities" described in a later section.

Background Information for Teachers

Surface tension acts like an invisible film on the surface of water or any other liquid. The surface tension of water is strong enough to support water that rises a short distance above the top of a container, enabling the water to "heap."

Surface tension is caused by the natural attraction that occurs among molecules. In any container of water, all of the molecules attract one another in all directions with a particular force. The molecules at the surface, however, have a stronger attraction for one another, because there are no water molecules above them to attract.

Diagram of Water Molecules

Extension Activities

Students may learn more about surface tension by investigation of questions such as:

- If we used a taller glass, could we put more pennies in the water?
- What about a wider glass?
- How many drops of water will fit on a penny?
- If everyone tries it, will the results be the same?
- If not, why not?
- Does it make any difference which side of the penny they use, heads or tails, or if the penny is old or new?
- Suppose you add something to the water, such as salt, sugar, or soap. Would that affect the number of drops that will fit on a penny?

Animal Defenses

Overview

In this unit in the video, Rhonda uses the children's natural fascination with dinosaurs to teach the relationship between form and function. Children learn about predator-prey relationships and how the structure of each living thing adapts it to survive in its habitat. After discussing the ways that various animals protect themselves, she presents a scenario of a defenseless animal that lived in the time of the dinosaurs, and challenges the children to construct defenses on a paper cutout of the defenseless animal. The children's presentation of their work to the class is enhanced by use of the overhead projector.

By the end of 2nd grade, students should know that animals eat plants or other animals for food.
AAAS Benchmarks for Science Literacy

The unit is derived from the *Animal Defenses* teacher's guide in the Great Explorations in Math and Science (GEMS) series. The guide provides complete instructions for carrying out the unit, as well as reproducible dinosaur pictures and patterns for creating the overhead projector scenes with colored transparencies. Other units appropriate for primary children include "Hide a Butterfly," "Liquid Explorations," "Frog Math," and more. For further information, contact GEMS, Lawrence Hall of Science, University of California, Berkeley, CA 94720.

Lesson Plan

Objectives: Students will make models that illustrate how the structure of an animal can protect it from predators.

Materials:

- ✓ Tyrannosaurus rex cutout
- ✓ Defenseless Denny cutout
- ✓ cutout paper "ferns"
- ✓ plastic overlays for drama—sky and moon
- ✓ construction paper mountain for drama
- ✓ overhead projector
- ✓ animal models, or stuffed animals students bring from home
- ✓ construction paper sheets—large (11" × 17") sheets

for each group of students, a basket, box, or tray, containing:

- ✓ construction paper—different colors and scraps
- ✓ scissors (one per child)
- ✓ glue (can be shared, but one per child is better)
- ✓ cutout "Defenseless Dennys" (one per child)

Vocabulary—(The following list is given, in the hope that, through conversations and writing, children will become familiar with them. It is not intended that children memorize these words or be quizzed on them.)

- defense, adaptation, herbivore, carnivore, omnivore, protection, predator, prey

Procedure

1. Using classroom pets, models, pictures, stuffed animals, etc., discuss the many ways that animals' structures and behaviors protect them from predators, the elements, etc. Many dinosaurs were protected by teeth, claws, plates, spikes, long tails, etc. Examples of modern-day defenses from predators include a cat's teeth and claws, a skunk's odor, a turtle's shell, a deer's long legs, a rabbit's protective coloration. The polar bear's fur and a bird's feathers protect them from cold. Desert creatures protect themselves from heat by staying underground during the day, and coming out at night.

2. Make up a drama of a defenseless animal, using the cutouts of the Tyrannosaurus rex, the defenseless animal, and paper ferns. Tell the class that they are going to see a story about a make-believe animal that lived in the time of the dinosaurs. Show them the cutouts of the defenseless animal, the Tyrannosaurus rex, and the ferns at appropriate times during the story. The script might go something like this:

   "This is a story of an animal that lived in the time of the dinosaurs. It has no teeth, no claws, no tail, no plates, nothing to protect it from the fierce Tyrannosaurus rex. Tyrannosaurus rex is looking for something to eat, so the defenseless animal has to hide in the ferns. S/he's hungry too, but s/he can't come out, for fear of T. rex. What can we do to protect this poor animal, so s/he can come out and get something to eat?"

3. Follow suggestions from the children about defenses to add, cutting claws, teeth, etc. from paper and glue them on.

4. Put the animal back in the ferns. Have T. rex return. Now the animal can go out of the ferns when s/he's hungry, to look for food, because of the defenses.

5. Tell the class that they will have their own defenseless animal cutout to "protect."

6. Distribute the baskets with the defenseless animal cutouts, paper, glue and scissors, and allow children to construct defenses for the animal.

At the elementary level, students should take responsibility for graphic and oral presentation of results.
New York State Frameworks

7. When some of the children are almost finished, introduce extension activities, such as writing, reading, constructing dioramas or trioramas.

8. When all of the children are finished constructing their defenses, continue the story, using the overhead projector. Use overlays of the mountain, sky and full moon for background. Have the Tyrannosaurus rex "walk" across the screen, describing the action:

   "Here's Tyrannosaurus rex. He's out looking for food again. Out in the distance, he sees some animals. Will he be able to eat them?

9. Call the children up to the overhead projector, one at a time, to show the defenses they have constructed and describe how they protect the animal.

Background for Reference

There is a relationship between the structure of an animal or plant and its survival. Animals that live in cold climates are protected from the elements by having fur or feathers, or by their ability to hibernate. Desert animals are protected from heat in various ways, such as living underground, being nocturnal, having thick skin to prevent drying, etc. Predators are animals that hunt and kill other animals for food. Many factors may protect against predators, including claws, teeth, plates, intelligence, camouflage, speed, and instinctive habits.

Predators may also be called carnivores (meat-eaters). Predators are adapted for their job by having sharp teeth and/or claws, and the ability to move quickly. The animals that they kill are called prey. Sometimes an animal that is prey for one animal can be a predator for another. For example, a frog can be a predator to an insect, but prey for a snake. Animals that eat only plants are called herbivores. Omnivores eat both plants and animals.

Plants and animals have features that help them live in different environments.
AAAS Benchmarks for Science Literacy

In later grades, children will learn about food chains, and the importance of plants to all living things.

Extensions—Making a Triorama

Problem: In what kind of habitat did the dinosaurs live?

Materials needed:

- ✓ large pieces of construction paper, cut into squares
- ✓ smaller pieces and scraps of construction paper and other materials to create the scenery
- ✓ scissors
- ✓ glue

Procedure

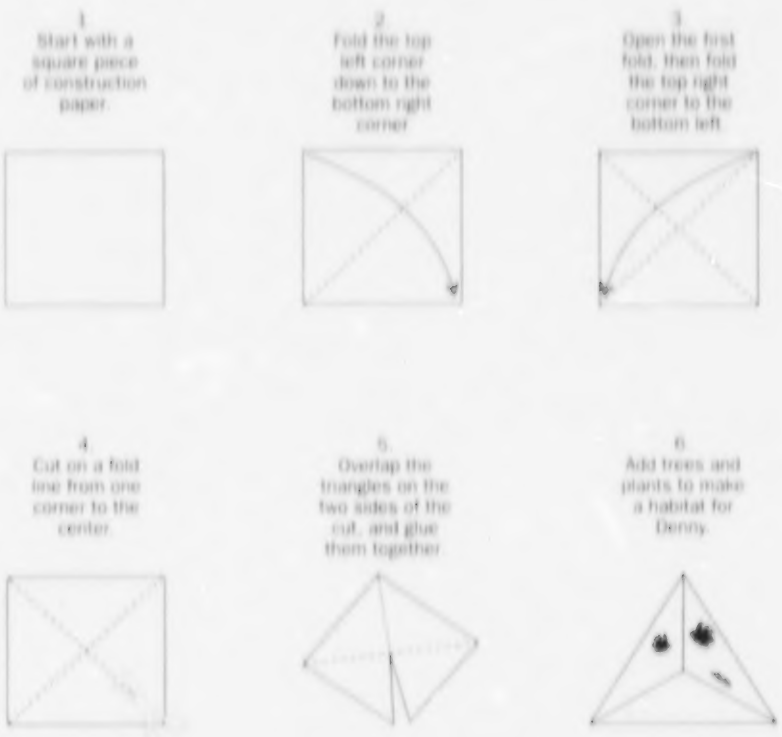
1. To make the construction paper into a square, fold the paper diagonally from one corner, so that the short side is even with the long side next to it, and cut off the extra paper that is not part of the square. See diagram below.
2. Unfold the first fold, and fold it again on the other diagonal, as in the diagram.
3. Cut a slit from one of the corners, along the fold line, to the center.

At the elementary level, students should produce objects and/or dioramas from familiar resistant and malleable materials.
New York State Frameworks

4. Overlap the two segments of paper closest to the slit, and glue them in place, forming a three-sided "stage" for their scenery.

5. Students can make a habitat in which dinosaurs and other animals lived. Would there be polar bears in the triorama?

Making A Triorama


1
Start with a square piece of construction paper.
2
Fold the top left corner down to the bottom right corner
3
Open the first fold, then fold the top right corner to the bottom left
4
Cut on a fold line from one corner to the center.
5
Overlap the triangles on the two sides of the cut, and glue them together
6
Add trees and plants to make a habitat for Denny.

Learning Styles

The extension activities used in this lesson were designed to appeal to a wide variety of learning styles. Most children find the basic assignment interesting and challenging, and some want to extend this type of activity by doing the triorama, placing their animal in its habitat. Others prefer putting their experiences into words by writing about them. Their writ-

ings can be shared with the class, along with the overhead projector presentation. The activity pack mentioned in the video was gathered from various sources. It contained activity sheets, puzzles, and word finds, which were chosen by some of the children. Although children work individually on their "Defenseless Denny," they often prefer to work with a partner on the extension activities.

Land Snails

Overview

In this kindergarten lesson in the video, Carolyn Mantek uses a visit from land snails as a theme to build an integrated unit that includes literature, drawing, and making models from clay and paper. By observing land snails, students are motivated to sharpen their powers of observation and become familiar with a nonthreatening living thing, whose structure, function, habits, and habitat may be very different from other animals they have observed.

Lesson Plan—Observing Snails

Problem: What are snails like?

Materials: Land snails—these can often be collected in the wild in some areas. (Gardeners will thank you for removing them.) They can also be ordered from Connecticut Valley Biological Supply, 82 South Valley Road, P.O. Box 326, Southampton, MA 01073, or phone 1-800-628-7748. (Their catalog # 35A is the largest and easiest to observe.) Some fish markets also sell snails, but it is important to get land snails, and not the ocean variety.

- ✓ petri dishes (optional)
- ✓ medicine droppers, dropping bottles or spray bottles with water
- ✓ magnifiers
- ✓ carrot sticks (or lettuce, or various other vegetables)
- ✓ chalk
- ✓ habitat—a small aquarium, large jar or other container
- ✓ soil

Procedure

1. Discuss with children what they already know about snails. They may be familiar with ocean or freshwater snails. Make sure they know that the snails they will observe are land snails, which would drown if submerged in water. Try not to comment on the rightness or

wrongness of their statements. It may be more appropriate to ask questions such as, "What do you think?" or "How do you know . . . ?" For 1st and 2nd graders, you may want to write down their statements, or to use the K-W-L format: What We KNOW, What We WANT to Know, and later, What We LEARNED.

2. Discuss the care and treatment of living things, emphasizing their small size, compared to the children.

3. Distribute the petri dishes and snails for children to observe. (Don't give a snail to a child who appears to be afraid, or doesn't want one. The child will usually change his or her mind later.) It may be necessary to place a few drops of water inside the shell to wake the snail up. (For impatient kindergartners, it's a good idea to spray the snails with water about a half-hour before the lesson, to wake them up.)

4. In small groups, encourage the children to observe the snail and its behavior. Suggested questions:

   - What are those things on the snail's head?
   - Are they all the same?
   - What are they used for? What makes you think so?
   - What happens when you touch them (the antennas)?
   - What happens if you turn the dish upside down? Will the snail stick?
   - Looking through the transparent petri dish, what can you observe about the way the snail moves?
   - Looking through the petri dish, can you see a dark area near the front? What do you think it is? Why?
   - Is your snail a tightrope walker? Can it walk on your pencil?

5. Distribute magnifying glasses for a closer look. Some children may need instruction and practice on their use. If the magnifier has two lenses, the smaller one with the greater curvature will magnify more.

6. Distribute carrot sticks to feed the snails. If the snail is hungry, it will make a visible depression in the carrot in a few minutes. You may want to offer the snail different types of food to determine preferences.

7. After children have observed the snails, collect them and return them to their habitat. Gather children together and discuss their observations.

Learning Centers

Materials to set out at each center:

Clay Modeling

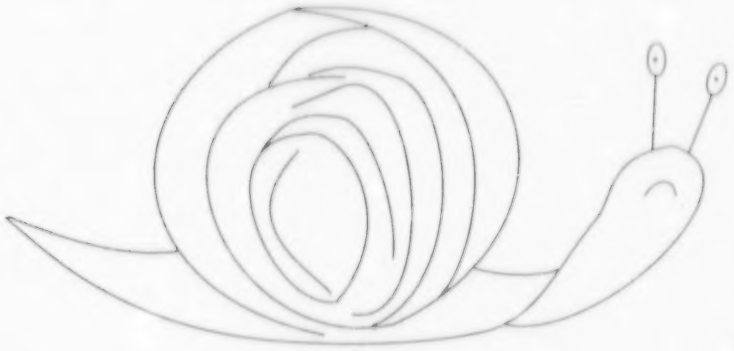
- Clay
- Toothpicks for antennas
- Tray for the finished product

Paper Construction

- Glue, crayons
- Precut pieces of construction paper:
- for shell 3" × 24", 3" × 18", 3" × 12"
- for body 3" × 12"
- small, narrow pieces for antennas.

Demonstrate the procedure for making the snail by forming the three shell strips into circles, one at a time, gluing them on to the body, starting with the largest, adding the antennas, and drawing on the mouth.

Making a Paper Snail



Drawing & painting

- Paper, pencils, easel, brushes, paints, snails
- These are set up in the usual places, with a safe place for the snails to serve as "models."

Listening/Reading

- Copies of books, tape recorder, headphones—If these are not available, various books on snails and other animals may be provided in a comfortable place to read.

Integrating Literature

The story shown in the videotape is *The Snail's Spell*, by Joanne Ryder, with illustrations by Lynne Cherry. It is a fanciful story of a child who pretends to be a snail, shrinking smaller and smaller, as the scale of the surrounding flora and fauna grow by comparison. While children obviously enjoy imagining themselves as snails, and studying the beautiful detail of the illustrations, they learn accurate information about the snail, which they may try to confirm by actual observation. It is easy for children to see the difference between fantasy and reality in this book. Notice how Carolyn engages students in the story by having them pretend to be snails, using motions.

By the end of second grade, students should know that stories sometimes give plants and animals attributes they really do not have.
AAAS Benchmarks for Science Literacy

Other books, such as *The Biggest House In the World*, by Leo Lionni, may be read in connection with this lesson, but in the course of discussion, children should come to realize that it is not a true story, but really a fable about the consequences of greed and materialism, which says more about people than about snails.

Land Snails in the Classroom

It is important for children to have the opportunity to observe a variety of living things. The land snail is an ideal classroom animal because it doesn't bite, doesn't carry diseases that humans can get, and it is highly unlikely that any child would be allergic to a snail. Land snails are relatively easy to obtain and care for, can survive long periods of famine and drought, and when the class tires of them, they may be stored in a refrigerator to hibernate for future classes. The snail's habitat can be any transparent container with a vented cover, such as a plastic aquarium, with holes in the lid. Put about two inches of soil in the bottom. A layer of leaves on top of the soil will help to keep the habitat a little cleaner, and provide extra food. Spraying them every day or two with water keeps them active and growing.

Science Background on Snails for Teacher Reference

Snails and their relatives the slugs are classified as gastropods, a class of molluscs. They live in both fresh and salt water, and some have adapted to life on land. Land snails inhabit damp places, where they live on leaves and other plant material. Some snail fossils are estimated to be more than 500 million years old, which places them ages before the appearance of dinosaurs.

Features That Children Can Observe

Shell—The shell is spiral in shape. The baby snail is born with a shell. As it grows, the shell grows, too, spiraling larger and larger, produced by a part of the snail called the mantle, just under the rim of the shell. The shell provides shelter from predators. It is part of the snail, not something the snail can crawl out of.

Foot—The foot is the part of the snail that sticks out of the snail's shell. It is actually the main part of the snail's body, and is responsible not only for locomotion, but most other body functions.

Locomotion—The snail moves in tiny wavelike motions, which are visible through transparent plastic or glass. Snails can walk up walls, across ceilings, even "tightrope-walk" along string or pencils, aided by the sticky, slimy mucous that they secrete. The mucous also serves as protection, lubricating the body from sharp and rough surfaces. A snail can climb over the edge of a razor blade without getting cut, because its slime protects it.

Antennas—The land snail has two pairs of antennas. The larger ones, on top of the head, have eyes, which look like small black dots, at the ends, while the shorter ones act as feelers and tasters. Students may touch the antennas lightly to observe the reaction: The antennas retract when touched. In some snails, the eyes are at the base of the antennas.

Mouth—When the underside of the snail is observed through transparent glass or plastic, the mouth may be visible. It is a brownish crescent-shaped structure near the front. The mouth contains a tongue (radula) that has thousands of tiny teeth on it. The teeth act as a file, scraping bits of food that the snail then swallows.

Air hole—The snail breathes through an opening near the rim of the shell. When the snail is hurt or uncomfortable, it may blow bubbles through this hole.

Anus—The anus is located very close to the air hole, but is difficult to observe, except when feces are being eliminated. Children need to know that elimination of wastes is a normal function of all living things. The color of the feces will vary, according to what the snail has eaten.

Reproduction—Most land snails are hermaphroditic, which means that both kinds of sex organs are located in each animal. However, they must mate to reproduce. When they mate, they exchange sperm, each one fertilizing the eggs of the other. The eggs are translucent and milky looking, about a half-centimeter in diameter. They are deposited in clusters in the soil or under leaves. They hatch in about two weeks into tiny snails that look exactly like the parents, complete with shell.

Other organs—The snail's body contains heart, kidneys, intestines, and sex organs. These usually remain inside the shell, even when the snail's foot is fully extended.

Food—Land snails are primarily herbivorous, and will eat most plant materials—lettuce, carrots, celery, leaves. However, they will also eat dead insects, slugs, earthworms, etc. They also need to have a supply of calcium to provide the raw material for their shell. This can be supplied by ordinary blackboard chalk, or by eggshells. In the wild, the land snail can eat limestone! This may be considered one of nature's recycling projects, since limestone is a rock that is formed from the shells of snails and other sea creatures that lived many ages ago.

All students must have the opportunity to observe a variety of plants and animals.
AAAS Benchmarks for Science Literacy

Hibernation and estivation—Snails survive the winter by crawling into the ground or under dead leaves to hibernate. A snail can survive dry spells by going into its shell and sealing the opening with a layer of dried slime. This process is called estivation.

About Observation and Assessment

Assessment must be embedded in the teaching and learning process rather than "delivered" out of context.
New York State Frameworks

One of the most important skills that children of primary age need to develop is observation. Teachers can help their students develop this skill by giving them a variety of living and nonliving things to observe, and asking children to describe their observations in spoken or written words, or, for young children, in pictures. The amount of accurate detail in children's drawings and paintings is a clue that a teacher can use to assess what the child has noticed in his or her observations.

Using Magnifiers

To help students notice smaller details, children should have ready access to magnifiers and some guidance in their use. Have the child start by holding the magnifier close to the eye and the object being observed, and gradually adjust the distances until the object is seen clearly. Most magnifiers used in classrooms have two lenses. The larger, less curved one is for general use, while the smaller, more curved lens gives a greater magnification.

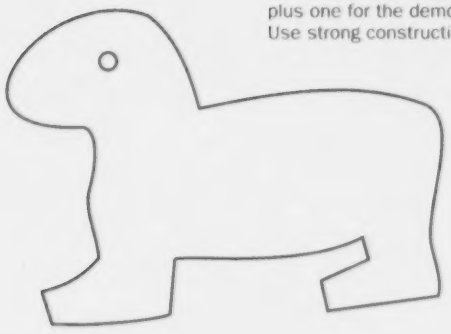
It is common for children to think that the larger lens produces a higher magnification, and it is often difficult to change that perception. It will help to give them practice observing fine print or the colored dots on the funnies before the snail lesson.

At the elementary level, students: make observations of objects and events, using the senses and instruments that extend the senses.
Draft, New York State Frameworks

"Tyrannosaurus Rex" Pattern

Cut one from
construction paper

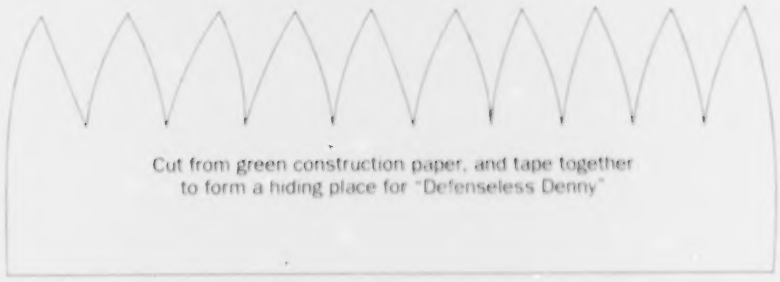
"Defenseless Denny" Pattern



Cut one for each student,
plus one for the demonstration.
Use strong construction paper.

57

"Ferns" Pattern

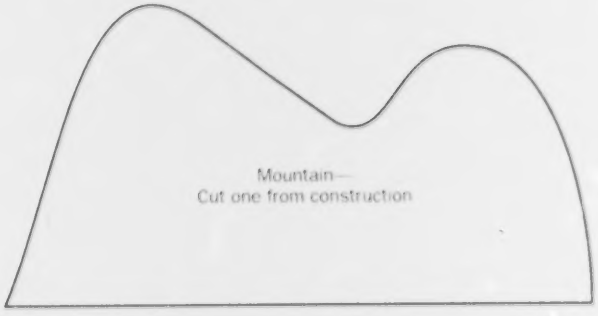


Cut from green construction paper, and tape together
to form a hiding place for "Defenseless Denny"

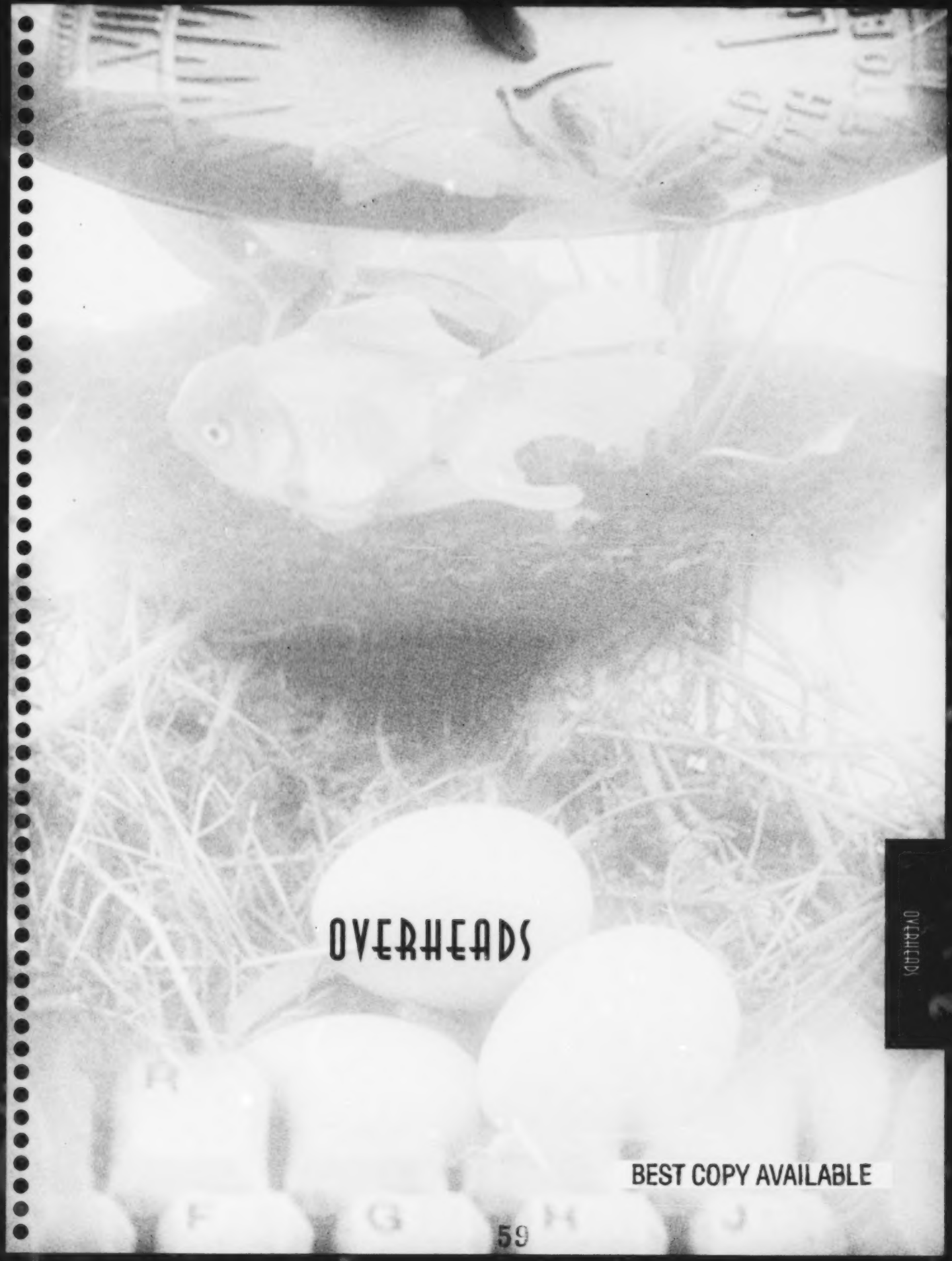
"Mountain and Moon Overlays" Pattern

Moon—
Cut one
from yellow
transparency

Background—
full sheet of blue
transparent plastic



Mountain—
Cut one from construction



OVERHEADS

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OVERHEAD 1

Objectives for the Workshop

At the end of this program, participants will be able to:

- **Explain the significance of documents such as the NRC Science Standards, AAAS Benchmarks, and science frameworks.**
- **Understand how to design a lesson that incorporates some of the science standards and demonstrates effective management of materials, questioning techniques, integration, and authentic assessment.**
- **Describe the role that elementary science plays in preparing students for life in a technological information age.**
- **Recognize the motivational value of hands-on science activities.**
- **Identify issues and concerns involved in implementing science standards.**
- **Develop a personal or group plan of action related to the science standards.**

ASCD
Association for Supervision and Curriculum Development

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Lionni, L. (1968). *The Biggest House in the World.* New York: Dragonfly Books, Alfred A. Knopf.

Ryder, J. (1982). *The Snail's Spell.* Illustrated by Lynne Cherry. New York: Scholastic Inc., 730 Broadway, New York, NY 10003, by arrangement with Puffin books, a division of Viking Penguin Inc.

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The following books contain wonderful photographs of snails. (The reading level of the text is too difficult for most primary children.)

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CURRICULUM
UPDATE

Reinventing Science Education

Reformers Promote Hands-On, Inquiry-Based Learning

In Lisa Nyberg's classroom at Brattain Elementary School in Springfield, Ore., 3rd and 4th graders are learning about simple machines. The classroom is a flurry of activity, as children take apart broken toasters and other household appliances, trying to identify the simple machines within. Students examine and test the mechanical workings intently, discussing their ideas with their partners. A child disassembling a tape recorder forms the theory that pushing a certain button works a switch. Another child is consulting the resource books scattered around the room, searching the index of *How Things Work* for "vacuum cleaners." When the children discover inexplicable components—such as electrical circuits and computer chips—they are eager to learn more.

LINDA ARMSTRONG

Giving students experiences with real phenomena is central to the reform agenda.

Across the country, in Michele Bartlett's earth science class at Rundlett Junior High School in Concord, N.H., 8th grade students are participating in an international ozone monitoring project. Using filter-paper badges, students collect smog data locally and then share their findings via the Internet with students at 80 other schools around the world. Bartlett's students also graph and analyze the data. In the process, they learn vocabulary such as "nitrous oxide" and "parts per billion" without having to resort to rote memorization. Students also submit their data to the Air Quality Board, the governor, and the National Student Research Center. Because they care about air quality, and because they are collecting real data to be shared with others, students take their work seriously.

If these students had been born only a few years earlier, their experiences in learning science might have been starkly different. Science education has traditionally followed the "teaching by telling" approach. Teachers have relied heavily on textbooks and lectures to convey large quantities of information, and students have been expected to memorize reams of facts and terminology. Hands-on experiences have typically been limited to "cookbook labs" with outcomes known in advance, not real investigations. In most classrooms, science has been presented as an inert body of knowledge to be assimilated, rather than a process of inquiry and a way to make sense of our world.

The traditional "telling" approach has allowed science teachers to cover a great many topics. But the quality of student learning that it has yielded has proven disappointing, experts in the field say. Many students can parrot what they've been taught, but their understanding of science concepts is often seriously flawed. Students' prior misconceptions, for example, stubbornly resist change.

Even on standardized tests, which emphasize recall over reasoning, student achievement has been lackluster. According to the most recent data from the National Assessment of Educational Progress, "Compared to 1969–70, average [science] achievement in 1992 was higher at age 9, essentially the same at age 13, and lower at age 17."

Willis, S. (Summer 1995). "Reinventing Science Education." *Curriculum Update*, 1–8.

Perhaps worse, the "telling" approach bores and alienates many students, who stop taking science courses as soon as possible. As a cohort of students progresses through high school, the number enrolled in science classes drops by roughly half each year, experts say. And the students who typically stick with science courses and succeed in them—students who are highly verbal and have good memories—do not necessarily make the best scientists.

Faced with these problems, the science education community is working zealously to reform itself. Major organizations—such as the National Science Foundation (NSF), the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and the National Academy of Sciences—are vigorously promoting the kinds of hands-on, inquiry-based activities described at the beginning of this article.

Reformers have set forth, in detail, a new vision for science education. Strong themes in the reform literature include the following:

- Learning of concepts should be emphasized over memorization of terms and facts.
- Students should have ample opportunities for hands-on learning. Concrete experiences with actual phenomena should precede more abstract lessons.
- Science instruction should be inquiry-based, at least in part. Students should have opportunities to pose their own questions, design and pursue their own investigations, analyze data, and present their findings.
- Teachers should explain concepts thoroughly before introducing the terminology associated with them, to ensure real understanding rather than parroting.
- Teachers should teach fewer concepts, in greater depth, rather than covering a great many topics superficially. ("Less is more.")

A Snapshot of the Field

How does science education play out on a day-to-day basis, in classrooms across the United States? Findings from the 1993 National Survey of Science and Mathematical Education, conducted by Horizon Research, Inc., with funding from the National Science Foundation, shed light on this question. The survey gathered data from approximately 6,000 U.S. teachers of math and science in grades 1–12 about their beliefs and practices. It also gathered data from department heads and lead teachers about their schools' science programs. Some illuminating findings follow.

Science Instruction

- Although use of hands-on activities has increased since the mid-1980s, science teachers still rely heavily on lectures and textbooks.
- The vast majority of science classes use one or more commercially published textbooks or programs, including 95 percent of middle and high school science classes. At the elementary level, 75 percent of science classes use published textbooks or programs, down from 86 percent in 1986.
- Looking across all science classes, the largest proportion of class time is devoted to lecture and discussion (38 percent), followed by hands-on or laboratory work (23 percent), individual seatwork (19 percent), and nonlaboratory small-group work (10 percent), with the remaining 10 percent of time spent on noninstructional activities.
- Sixty percent of high school science and math classes listen and take notes during presentations by the teacher on a daily basis; 94 percent do so at least once a week.
- More than 60 percent of high school science classes never take field trips, 54 percent never use computers, and 43 percent never work in class on science projects that last at least a week.

Teachers' Goals

- According to teacher reports, the most heavily emphasized objectives in science classes are learning basic science concepts (heavily emphasized in 83 percent of science classes overall), increasing awareness of the importance of science in daily life (77 percent), and developing problem-solving and inquiry skills (74 percent).
- Approximately 20 percent of science classes in each grade range put heavy emphasis on preparing students for standardized tests.
- Teachers in classes with high proportions of minority students are more likely than others to emphasize preparing students for standardized tests, and less likely to aim toward preparing students for further study in science and math.

Time Devoted to Science

- In elementary classes, an average of only about one-half hour per day is spent on science instruction. This figure has increased slightly over the past 15 years.
- Students are typically required to take two years of science in high school.

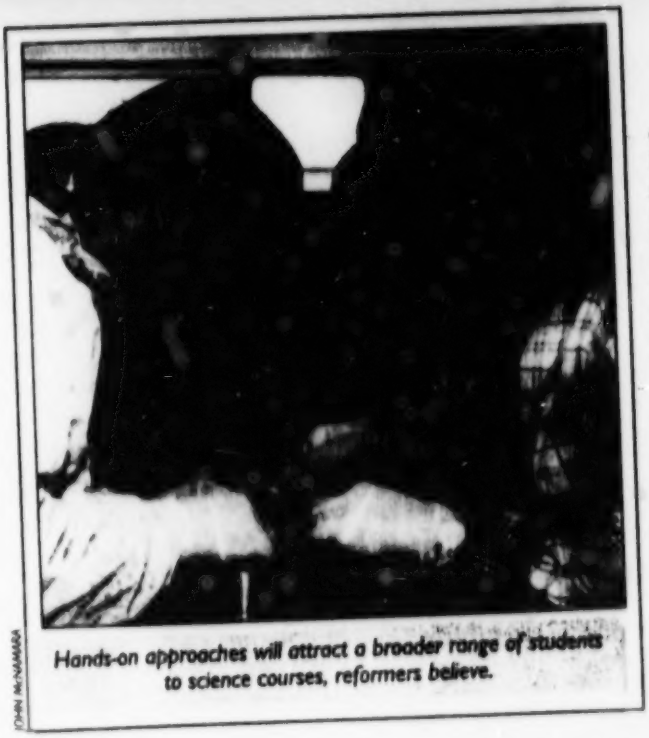
Diversity Issues

- Non-Asian minority students are particularly likely to "drop out" of science and math course taking.
- The proportion of science and math teachers who are themselves members of minority groups is very low—only about 11 percent in the elementary and middle grades and 7 percent at the high school level, at a time when roughly 30 percent of students belong to minority groups.

Equipment Needs

- Many science teachers indicated that certain kinds of equipment they need are unavailable. The most frequently cited needs were for running water, electrical outlets, gas for burners, and hoods or air hoses in laboratories, as well as videodiscs and CD-ROM players.

Adapted from *A Profile of Science and Mathematics Education in the United States: 1993*, by Iris Weiss of Horizon Research, Inc., 111 Cloister Court, Ste. 220, Chapel Hill, NC 27514-2296. ●



JOHN MCNAMARA

Hands-on approaches will attract a broader range of students to science courses, reformers believe.

- Students should have opportunities to *apply* science knowledge and to make connections between what they learn and their everyday lives.
- Teachers should build on students' prior understandings and prod them to rethink their misconceptions.
- All students should become science literate, not just the college-bound. Schools should prepare science-literate citizens, not just future scientists.
- Educators should begin to integrate the various science disciplines (biology, chemistry, physics), as well as integrating science with other subject areas.

The "overarching theme" of these reform ideas is constructivism, says Dennis Cheek, who coordinates mathematics, science, and technology for the Rhode Island department of education. The focus is on "allowing students to make meaning for themselves" through active learning experiences, rather than just barraging them with information.

These reform ideas are "absolutely vital," says Anthea Maton, a science education consultant from Oklahoma City. There's a big difference between teaching from the textbook and making sure students grasp concepts, she asserts. Students who only *know* the science they're learning and students who truly *understand* it are "poles apart."

Maton cites the example of a class she observed where a student incorrectly used the term *inertia* instead of *momentum*. If teachers introduce these terms without having students explore and discuss the associated concepts thoroughly, she says, students' understanding of the terms may be limited to "if something moves, it has it."

Inquiry-based learning yields deeper understanding because it focuses on the question "How do we know?" says Gerhard Salinger, a program director at the National Science Foundation. Although teachers can simply *tell* students facts—for example, that the earth has seasons because it rotates on a tilted axis—students will understand (and remember) such concepts better if they explore why we believe them to be true. Experimenting with a flashlight and tennis balls, he suggests, can help students truly understand what causes the seasons—and gives the teacher an opportunity to confront the misconception that, during winter, the entire earth moves farther from the sun.

These reform ideas are not new, experts in the field readily admit. Yet, from his visits to classrooms, Cheek has found "there's still an awful lot of 'chalk and talk' going on." Many teachers still place more emphasis on maintaining "control and quiet" than on using active, hands-on approaches that help students gain real understanding. Implementation of these ideas has a long way to go.

Major Reform Efforts

Several massive reform efforts are aimed at changing that situation. The National Science Foundation, for example, is funding statewide systemic initiatives to promote reform. Other high-profile efforts include NSTA's Scope, Sequence, and Coordination project, AAAS's Project 2061, and the new National Science Education Standards project.

Scope, Sequence and Coordination of Secondary School Science (SS&C) is a reform effort of the National Science Teachers Association (NSTA). SS&C recommends that all students study each science discipline—biology, chemistry, physics, earth and space science—every year for six years (in grades 7–12).

This approach is a radical change from the prevailing "layer-cake curriculum," in which students study earth science in 9th grade, biology in 10th grade, chemistry in 11th grade, and physics in 12th grade. (More than half of all students don't take a science course after 10th grade, and only 19 percent take a course in physics, according to NSTA literature.) The SS&C approach spreads out the study of each science discipline over several years. It also features hands-on, inquiry-based instruction.

When students study each science discipline beginning in the middle grades, courses like chemistry and physics don't seem so "foreign" to them when they are juniors and seniors, says Thomas Sachse, executive director of the California Science Project, a statewide staff development network. And because students learn these disciplines gradually, without complex math at first, they develop "an affinity, not a fear" for them, he adds.

SS&C is "trying to provide a substantial level of understanding [in each science discipline] for all students, in a society where people believe that most students can't learn it," says Bill Aldridge, NSTA's executive director. Most people, including science educators, sincerely believe that science at certain in-depth levels can't be learned by everyone, he charges. Yet the evidence against this belief—from countries that teach demanding science to a far greater proportion of students than the United States does—is "overwhelming," he says.

Typical science courses put "all the abstractions at the beginning" and emphasize the memorization of facts and processes—an approach that "basically sorts people out," Aldridge says. By contrast, SS&C modifies the curriculum in accordance with the research on how students learn. As a result, "essentially all kids can learn it."

Since 1990, SS&C has been implemented at the middle-school level at six pilot sites. Now, a newly launched study of 15 high schools implementing SS&C will "put it to the test," Aldridge says. He hopes the independent evaluation will show "dramatic" results, especially for minority students. Just showing a positive effect will not spur broad-scale change, he believes.

Project 2061, a long-term reform initiative of the American Association for the Advancement of Science (AAAS), addresses science, mathematics, and technology, says Jo Ellen Roseman, the Project's curriculum director. It focuses on the curriculum, because curriculum is "central to the reform effort." The Project's philosophy is set forth in two major publications, *Project 2061: Science for*

All Americans and *Benchmarks for Science Literacy*.

Science for All Americans, published in 1989, defines "a clear set of adult literacy goals in science, mathematics, and technology for everyone," Roseman explains. *Benchmarks for Scientific Literacy*, released in 1993, suggests concepts to introduce at grades 2, 5, 8, and 12 that would constitute "reasonable progress" toward the literacy goals. Where the benchmarks and the draft national standards for science education overlap (natural science and technology), they are "overwhelmingly the same," Roseman says, and thus mutually reinforcing. (For more on the national standards, see box, below.)

According to *Science for All Americans*, Project 2061 envisions a science curriculum in which

• the amount of detail that students are expected to retain is considerably less than in traditional courses, so that important concepts can be explored in some depth. Ideas and thinking skills are emphasized at the expense of specialized vocabulary and memorized procedures.

• boundaries between traditional subject-matter categories are softened and links are emphasized, so that students will appreciate connections among ideas.

• some topics rarely found in school curriculums are addressed, including the nature of the scientific enterprise, important episodes in the history of science and technology, and the major conceptual themes that run through almost all science thinking.

Project 2061 recognizes that curriculum reform is "necessary but far from sufficient" to transform science education, Roseman says. To support other aspects of reform, AAAS is producing computer disks of descriptions of recommended professional development resources and teaching materials. (The former will be available by

National Standards Seen as a Catalyst for Reform

Science, like many other subject areas, will soon have a set of national standards to bolster the efforts of reformers. Developed by the National Research Council (an agency of the National Academy of Sciences and the National Academy of Engineering), the *National Science Education Standards* have been widely disseminated in draft form. The final version is expected to be published this fall.

Unlike some similar efforts in other subject areas, the science standards take a systemic approach. Beyond spelling out important science content, they describe the kind of teaching, professional development, and assessment the field should provide. The draft document also includes "program standards"—criteria for judging school science programs—and "system standards," which address resources and coordination at the state and federal levels.

Not surprisingly, the science standards promote the major themes in the reform literature. The standards document states the following principles, among others, at the outset:

• All students should have the opportunity to attain higher levels of scientific literacy than they do currently.

• All students will learn all science in the content standards.

• All students will develop an understanding of science that enables them to use their knowledge in personal, social, and historical contexts.

• Learning science is an active process.

• For all students to understand more science, less emphasis must be given to some science content and more resources must be devoted to science education.

Development of the standards began in 1992, with broad input from scientists and science educators. The fourth and last round of review began in December 1994. Close to 40,000 copies of the draft document have been distributed, half to individuals and half to focus groups of teachers, professors, businesspeople, and scientists.

"I am relieved to say that most of the responses are very positive," reports Angelo Collins, director of the National Science Education Standards Project. One complaint some reviewers have made, however, is that the draft document is too long. "No one has suggested something to take out, though," Collins notes wryly. Other reviewers have criticized the standards for failing to capture adequately the *quantitative* aspect of science—a concern that will prompt some revisions, Collins says.

The content standards focus on fundamental concepts—the "big ideas" such as motion, force, matter, energy, evolution, and genetics—rather than bogging down in numerous topics, factoids, and technical words, says Rodger Bybee, who served as chair of the working group on science content standards. Bybee is associate director of the Biological Sciences Curriculum Study (BSCS).

The content standards also attempt to broaden science learning beyond a narrow focus on life, earth, and physical sciences, Bybee says. Therefore, they include several other categories as well: science and technology, science in personal and social perspectives, history and nature of science, unifying concepts and processes, and science as inquiry.

According to the standards document, inquiry "involves making observations, posing questions, examining books and other sources of information to see what is already known, planning investigations, reviewing what is already known in light of experimental evidence, proposing answers and explanations, and communicating the results."

The content standards represent fundamental concepts that *all* students should grasp, Bybee says. "We're focusing on the question, 'What should all citizens know and be able to do?' not 'What do students need to know to get into graduate school?'"

The standards are "silent" on the question of how the curriculum should be organized, Bybee points out. They do not pass judgment on the layer-cake curriculum, interdisciplinary approaches, or AP courses, for example. States and districts must determine what form the curriculum should take, he says.

Teaching Standards

Although the science standards also address teaching, they *don't* say, "This is the one way to teach," notes Karen Worth, who served as chair of the working group on science teaching standards. Worth is a senior associate at the Education Development Center and a faculty member in the graduate school of education at Wheelock College.

the end of this year; the latter, by late 1996, Roseman predicts.) Two other publications, *Designs for Science Literacy* and *Blueprints for Reform*, will help educators design K–12 science curriculums and pursue systemic reform, respectively.

What Teachers Need

The national science organizations are calling for reform, and teachers are listening. Do they like what they hear?

Teachers, as a group, have mixed feelings about the reform agenda (see box, p. 6). Those in the upper grades tend to be more resistant. The teachers interviewed for this article—all of whom have received Presidential Awards for Excellence in science—were enthusiastic about the reform ideas but described a variety of obstacles to implementing them.

To take a hands-on approach, teachers "constantly have to put together materials and activities," says Alfred Benbenek, who teaches 5th grade at Holt Elementary School in Whitman, Mass. Given small budgets for science materials, teachers have to "beg, borrow, and steal" materials such as cups, zip-lock bags, wires, batteries, and aluminum foil, he says. Because these things wear out, teachers are in constant need of them.

Teachers are eager to do hands-on activities, says Jane Carey, who teaches 2nd grade at Lancashire Elementary School in Wilmington, Del. Teachers are held back, however, by lack of direction about what to do, lack of materials (without scrounging), and lack of training, which makes them "hesitant to jump in."

Carey teaches a unit on "sinking and floating" in which students test a variety of objects to see whether they sink or float, then try to turn a "sinker" into a "floater" and vice versa. The class makes a chart of materials and their properties. Then students apply what

Because the standards promote science as inquiry, they ask teachers to help students become inquirers who learn basic concepts in the context of investigations. Worth acknowledges that this role will not appeal to all teachers. "There are teachers out there who still do not believe philosophically in teaching for understanding rather than [dispensing] information," she says. "If you're in the 'they-really-should-know-these-facts' camp, you won't want to do this." Teachers who want students to construct their own understandings, on the other hand, will find the standards "an important validation," she believes. These teachers "tend to be viewed as the fringe," she says. "Now they will be validated as the center."

The bottom-line message of the assessment standards is that educators should collect information about what students understand for a *variety* of purposes—not just to assign grades, says Audrey Champagne, who served as chair of the working group on science assessment standards. Champagne is a professor of chemistry and education at the University of Albany (SUNY).

The new emphasis on inquiry and reasoning skills poses a challenge for assessment, she notes. It's relatively easy to assess whether a student can use a balance to measure mass, for example—it's harder to assess whether the student can figure out that she *needs* to use a balance. Yet both kinds of abilities are important to assess.

Nothing New?

"To some degree, you could say there's nothing new in the standards," says Harold Pratt, who worked on the standards development team for more than two years. A former director of curriculum in Jefferson County, Colo., Pratt now directs an elementary science program for BSCS. The ideas reflected in the standards have been widely accepted in the field for many years, Pratt maintains. Yet "they are far from being implemented," he says. Implementation has been "our Waterloo."

The standards should be neither slavishly followed nor dismissed out of hand, Worth says. "This is not a perfect document, and it should not be followed perfectly—but it should be seriously considered."

The response of many teachers to the standards, however, is "You must be kidding," Worth concedes. Teachers' resistance is not so much a reaction to the philosophy embodied in the standards as to the fact that assessments and resources are not yet aligned with that philosophy. Even some teachers who fully endorse the standards say, "I'm not going to touch these until the rest of the world agrees and provides the resources we need for implementation." Worth calls this attitude "a well-founded cynicism."

Educators should not expect that teachers will pick up the standards and use them directly, Pratt says. "This is not a document that tells you what to do in your classroom tomorrow." The standards are "not a how-to document," Worth agrees. Instead, they are "a guide for decision making"—a set of criteria against which to weigh policy decisions, from the school level to the national level.

Perhaps unfortunately, the scope of the national standards does not, for the most part, extend to higher education, Pratt notes. "That piece is yet to be done—and it's an important part of the system."

The standards are one strategy for moving reform forward—not a panacea, Pratt says. But they will serve as "a catalyst for improvement," he believes. "They will focus our attention." Science educators should get acquainted with the standards and use them as a focus of dialogue and discussion, he advises.

Although the standards document is only in draft form, "the signs are that it's already had a big impact," Collins says. The standards are exerting an influence on state curriculum frameworks, textbook publishers, and professional development offerings, she says. The major organizations in science education are all promoting their implementation, she adds. For example, NSTA has already published *A High School Framework for National Science Education Standards* to help educators create programs based on the standards.

"The harder task lies before us," Bybee cautions. "It was relatively easy to develop the standards. But translating them into programs to help all students achieve higher levels of scientific literacy will be a tremendous task," he says. The "scaling up" will require a concerted, national effort. States and districts will have to devote resources to the endeavor, as will the U.S. Department of Education, the National Science Foundation, organizations such as NASA, and private foundations. "It's their move now." ●

The final version of the standards, anticipated next fall, will be sold by National Academy Press. For more information, contact the National Science Education Standards Project, 2101 Constitution Ave., N.W., HA 486, Washington, DC 20418, (tel.) 202-334-1399.

they've learned by creating a classroom aquarium. "If teachers had the time and resources," more ideas like this would flourish, Carey says.

Judy Morlan, who teaches 6th grade at Brownell Middle School in Grosse Pointe Farms, Mich., finds it "very difficult" to put constructivist principles into practice in her science teaching. She is frustrated by "a tightly packed curriculum" that she is held closely to. Because she must cover all the objectives, Morlan can't take the time to teach certain topics in depth, as she would like to do. In addition, trying to identify the misconceptions of a classful of children, and then working to change them, is very time-consuming.

"I feel like I'm in the middle," she says, because she is forced to compromise. "I'm a part-way person."

Morlan uses active learning "to make an impression on kids with the important things." For example, she has her students pace out the relative distance of the planets from the sun. "They respond to this sort of thing," she reports. She feels her efforts have been worthwhile when, for instance, a student exclaims, "Oh, my gosh—I didn't realize Pluto was *that* far from the sun!"

High school teachers are reluctant to change because they still feel accountable to colleges and universities, says Margo Murphy, who teaches 9th-grade environmental science at Georges Valley High School in Thomaston, Maine. Although Murphy herself doesn't teach from a textbook, most high school science is textbook-driven, she says. To create another kind of course demands "an enormous amount of work" from a teacher. It takes "a huge amount of time to convert" to an inquiry-based approach, she says.

Naturally, given these challenges, reformers are calling for more professional development for teachers of science. Teacher training is a big component of reform proposals, says Maton. "Nobody is advocating just *telling* teachers to teach this way."

Reform should *focus* on teacher education—both preservice and inservice, says Marvin Druger, chair of science teaching at Syracuse University and president of NSTA. "That's where the action should be." Many reformers are urging that undergraduate science courses become inquiry-based as well. Future teachers who have learned science in 300-seat lecture halls will not know how to foster active learning, they assert.

Teachers' Attitudes Toward Reform

Do teachers embrace the reforms in science education that national organizations are advocating? The 1993 National Survey of Science and Mathematical Education provides some insights. Conducted by Horizon Research, Inc., with funding from the National Science Foundation, the survey asked approximately 6,000 U.S. teachers of math and science in grades 1–12 about their training, pedagogical beliefs, and instructional practices. Here are some highlights from the findings:

Teachers Support Some Reform Ideas . . .

- Nearly all teachers believe hands-on activities should be part of science instruction.
- Most teachers believe that science instruction should provide students with concrete experiences before exposing them to abstract treatments. About 84 percent of high school teachers, and more than 90 percent of teachers at other levels, hold this view.
- Most teachers believe that students learn best when they study science in the context of personal or social applications. More than 90 percent of teachers at the elementary and middle school levels hold this view, as do 86 percent of teachers at the high school level.
- Most teachers support the use of cooperative learning in science classes. More than 80 percent of teachers at the high school level, and more than 90 percent of teachers at other levels, hold this view.

. . . But Resist Others

- Teachers are divided on the idea of emphasizing "depth over breadth." Only about 70 percent of elementary and middle grade teachers, and fewer than 60 percent of high school teachers, agree that science and math instruction should provide deeper coverage of fewer concepts.
- Many teachers resist the advice of reformers to teach science concepts *before* teaching the terminology associated with those concepts. Nearly one-third of teachers in grades 1–4, increasing to more than half of high school science teachers, indicated that "it is important for students to learn basic scientific terms and formulas before learning underlying concepts and principles."
- Although the reform literature calls for de-emphasizing factual learning in science, many teachers report that they emphasize this objective in science classes. Half of elementary science classes, and nearly 2 out of 3 in the middle and high school grades, put heavy emphasis on learning "important terms and facts in science."
- Many teachers doubt that heterogeneous grouping is the way to ensure success for all students. Roughly 3 in 10 teachers of grades 1–4 believe that students learn science and math best when grouped with peers of similar abilities. At the high school level, more than 7 out of 10 teachers hold this view.
- Although reform advocates tend to be critical of science textbooks, most science teachers are pleased with the quality of their textbooks. About 3 out of 4 teachers rate their science textbooks "good" or better.

Attitudes Differ by Grade Level

- Elementary teachers tend to be confident in their ability to use reform-oriented strategies such as cooperative learning. However, many do not feel confident in their ability to teach a number of elementary science content areas.
- High school teachers are more likely to have extensive preparation in their subjects, but they are less supportive of reform-oriented teaching techniques, less confident in their ability to use them, and less likely to do so in their classrooms.

Adapted from *A Profile of Science and Mathematics Education in the United States: 1993*, by Iris Weiss of Horizon Research, Inc., 111 Cloister Court, Ste. 220, Chapel Hill, NC 27514-2296. ●

Science courses have been too abstract and too mathematical from the outset, reformers charge.

In the reform literature, "textbook-driven" has become a pejorative term. Reformers of science education have criticized textbooks for abetting the "teaching by telling" approach.

Science texts in the United States differ from those used in other countries, says Senta Raizen, director of the National Center for Improving Science Education. U.S. textbooks "treat many topics in a scattershot fashion," whereas those in other countries treat fewer topics, in greater depth, and include far less review.

But U.S. texts are beginning to change, Raizen says. Textbook publishers try to follow state guidelines, she notes. "They're not nasties." But they can't prescribe how motivated teachers will be to encourage students' own investigations rather than lecturing from the textbook, she adds.

One 11th-grade textbook that anticipated the reform movement is *Chemistry in the Community*, developed in 1982 by the American Chemical Society. Now in its third edition, the book is "still considered rather nouveau," says Sylvia Ware, director of the Society's education division.

Chemistry in the Community was designed to correct the "mismatch" between chemistry instruction and students, Ware says. Most high-school chemistry serves best as an introduction for those who intend to earn a bachelor's degree in the subject—"but of course most students won't do this," she points out. Instruction is too abstract and too mathematical, Ware charges. "Chemistry doesn't have to be a quantitative discipline from Day One."

Unlike a traditional text, *Chemistry in the Community* examines issues in the community, to teach "chemistry for citizenship." The book is designed around eight issues: water needs, conserving chemical resources, petroleum, food, nuclear issues, air, health, and industry and its role in society.

Students using the text make lots of decisions and apply chemical knowledge, Ware says. In the first unit, for example, a scenario describes a "fish kill" in an imaginary river. Students investigate why the fish died, then hold a town meeting, where the facts come out. Then they must decide how to handle the problem.

"We're trying to rehabilitate the utilitarian," Ware says. "Knowledge can be useful—that's not a negative! If knowledge were only abstract, we'd never have got out of caves," she jokes.

Going Too Far?

Despite widespread enthusiasm for reform, some science educators fear that reform ideas may be taken to extremes.

"There seems to be a [misconception] that all science at all grade levels should be learned through inquiry," says Audrey Champagne, a professor of chemistry and education at the University of Albany (SUNY). Champagne finds this view too one-sided. In the early grades, inquiry-based learning can help students develop knowledge and reasoning skills that will enable them to learn in more traditional ways ("book learning") in the upper grades, she believes.

The heavy emphasis on inquiry may be an overreaction to the current overemphasis on facts, Champagne says. "Education in the United States is characterized by pendulum swings to the extreme."

Inquiry-based instruction is "a good idea in moderation," says David Haury, director of the ERIC Clearinghouse for Science, Mathematics, and Environmental Education. As students, "we all benefit from a *mixture* of experiences."

In today's climate of reform, there is a readiness to denigrate textbooks and lectures, Haury says. But when students' curiosity is aroused, they are receptive to reading or listening. And if students are to become science literate in 12 years of schooling, "some things must be told to them." Therefore, teachers should seek a "happy balance," Haury advises. "You don't have to throw away one [approach] to do the other."

Haury also has concerns about the "less is more" philosophy. Teachers embrace the idea, he says, but they are uncomfortable with having to defend the practice. Teachers are placed in an awkward position when they must respond to administrators or parents who ask, "Why aren't you teaching this formula or that set of facts?"

Paring down the curriculum in keeping with the "less is more" philosophy ought *not* to be done on an individual-teacher basis, says Carolee Matsumoto of the Education Development Center. It's "risky" for teachers to take a stand on their own; they are too vulnerable to attack. Instead, the school or district should develop a scope and sequence with input from science experts, teachers, parents, and others, she says.

Some science teachers are uncomfortable with the notion of de-emphasizing facts and terms. Paul Pomeroy, who teaches 12th-grade physics at Archmere Academy in Claymont, Del., believes the reform ideas are "incredibly good in many ways." But he also thinks the heavy emphasis on teaching concepts is "a misguided notion." What started as a push to *include* hands-on activities and opportunities to conceptualize is being "misconstrued by many as the only good way to teach science," he says.

Pomeroy agrees with reformers that "memorizing and spitting stuff back is horrible science." But students still need to know

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terms, facts, and how to compute, he says. And "there are times you have to get into the theory and muck through it."

College-bound students still need to develop the skill to "regurgitate" information, says C. Ford Morishita, who teaches biology at Clackamas High School in Milwaukie, Ore. Teachers of Advanced Placement (AP) courses *must* emphasize coverage and teach prescribed labs, he adds. "You can't cut content or you're cutting students' throats on AP exams."

Raizen also advocates using a mix of instructional strategies. "I'm someone who wants to make sure we don't throw out older styles of teaching," she says. However, most classes are still textbook- and lecture-oriented, she points out. "We're far from having the pendulum swing too far—yet."

The reform notion of extending science instruction to a much broader range of students also raises concerns.

Schools can't teach just a "literacy curriculum," says Morishita. "Bright kids need another level of opportunity." He worries that schools might phase out advanced single-discipline science classes and research opportunities. "We can't do 'science for all' at the expense of the high achievers," he says.

Pomeroy also fears that "in making sure every student gets some science, we may sell the top third of students short," by "diminishing the intensity" of their instruction. He is disturbed by the prevalent attitude that bright students will thrive, regardless of their school experiences. "A good student needs to be pushed too—and farther," he says.

"Science for all" is the subject of "a raging argument," Salinger of NSF says. One way of teaching that challenges *all* students—even "the really bright kids"—is to pose open-ended "design problems," he says. For example, a teacher could ask students to design a container to get a baked potato home hot from a fast-food restaurant. This problem requires students to set a standard for what "hot" is, measure the thermoconductivity of various materials, consider structural rigidity, and address environmental concerns. Different students could be encouraged to design their solutions under different sets of constraints, depending on their ability, Salinger adds.

Moving Beyond Experience

The reform movement in science education is promoting many very good ideas that make logical sense, Haury says. But how do educators actually put them into practice? "None of us have experienced it," he says of the new vision of active learning. "Trying to get large communities of people to think beyond the boundaries of their own experience—that's the challenge." ●

Resources

The following organizations can provide resources for improving science education.

American Association for the Advancement of Science, 1333 H St., N.W., Washington, DC 20005; (tel.) 202-326-6666; (fax) 202-842-5196.

National Science Teachers Association, 1840 Wilson Blvd., Arlington, VA 22201-3000; (tel.) 703-243-7100; (fax) 703-243-7177.

ERIC Clearinghouse for Science, Mathematics, and Environmental Education, The Ohio State University, ERIC/CSMEE, 1929 Kenny Rd., Columbus, OH 43210-1080; (tel.) 614-292-6717.

National Science Resources Center, Arts and Industries Bldg., Room 1201, Smithsonian Institution, Washington, DC 20560; (tel.) 202-357-2555; (fax) 202-786-2028. The NSRC collects and disseminates information about exemplary teaching resources, develops innovative curriculum materials, and sponsors outreach activities to help school districts develop and sustain hands-on science programs.

Eisenhower National Clearinghouse for Mathematics and Science Education, The Ohio State University, 1929 Kenny Rd., Columbus, OH 43210-1079; (tel.) 614-292-7784; E-mail: info@enc.org. The Clearinghouse maintains an up-to-date and comprehensive listing of mathematics and science curriculum materials.

National Association for Science, Technology, and Society (STS), Pennsylvania State University, 133 Willard Bldg., University Park, PA 16802; (tel.) 814-865-3044; (fax) 814-865-3047. NASTS promotes examination of the impact of science and technology on society and the environment.

National Center for Improving Science Education, 2000 L St., N.W., Ste. 603, Washington, DC 20036; (tel.) 202-467-0652; (fax) 202-467-0659; BITNET: sentar@gwuvm.gwu.edu. NCISE provides a range of products and services to policymakers and practitioners who are working to strengthen science education.

Biological Sciences Curriculum Study, Pike's Peak Research Park, 5415 Mark Dabling Blvd., Colorado Springs, CO 80918; (tel.) 719-531-5550. BSCS is a nonprofit organization that designs curriculums in the sciences.

Education Development Center, 55 Chapel St., Newton, MA 02158; (tel.) 617-969-7100. EDC is a nonprofit organization that does research and development work in education, including curriculum development. ●

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Student-Centered Inquiry

Ramon E. Lopez and Jan Tuomi

A national consensus is evolving around what constitutes effective science education. It is reflected in an array of publications, including *Science for All Americans* (1989), *Benchmarks for Scientific Literacy* (1993), and *National Science Education Standards* (1994). These documents share two common convictions: (1) all students, and especially underrepresented groups (Oakes 1990), need to learn scientific skills, such as observation and analysis; and (2) these skills should be imparted in a "less is more" curriculum that begins in elementary school before kids form negative attitudes toward science.

As any scientist knows, the best way to learn science is to do science. This is the only way to get beyond dry facts to the real business of science—asking questions, conducting experiments, collecting data, and looking for answers. In elementary school, the best way to accomplish this is to examine natural phenomena that are brought into the classroom and studied over time. Active, hands-on, student-centered inquiry, in which kids learn to apply scientific problem solving, should be at the core of science education.

Elements of Success

With new materials available, a better understanding of how to do things, and a national consensus that reform is critical to our future, many school districts have begun to reform their elementary science programs systemically, that is, to revamp all elements of the system and institutionalize the changes. What does this entail? Four basic components:

1. Good teaching materials. These should be research-based, developmentally appropriate, designed by educators and knowledgeable scientists, and thoroughly field-tested. They should enable children to conduct long-term investigations (say, eight weeks), not with a series of single-shot activities, but with activities that build upon one another. The activities should encourage inquiry, address a variety of learning styles, and connect to other parts of the curriculum.

Excellent examples of such materials are found in *Science and Technology for Children* (Carolina Biological), *Insights* (Optical Data), and the *Full Option Science System* (Britannica). As for costs, it is often no more expensive to maintain a hands-on science program than a textbook program. Schools should use their resources to buy the best curriculum for their needs, knowing that teachers may develop additions or modifications after some experience with the units.

2. A materials support system. Because teachers do not have time to gather the needed materials, a science kit should arrive at a specified time with the materials the entire class needs for several weeks. When the unit ends, the kit can be picked up, refurbished at a central location, and sent to the next scheduled teacher.

3. A vigorous and ongoing professional development program. Teachers need to work through the units themselves and learn how to teach them. They need to be able to ask questions—particularly about classroom management—of more experienced teachers. They may also need support to overcome their fear of science and to realize that they, too, can become scientists. Administrators also need to experience what hands-on science is all about in order to support and evaluate an innovative program. Both need to understand that the statement "I don't know, but maybe we can find out" is the starting point for all inquiry.

4. New assessment tools. A bad standardized test can cause teachers and administrators to resist a good hands-on program. Performance-based testing and portfolios are preferable. Teachers may need inservices in the new assessment techniques, and parents and school boards will have to be kept abreast of the changes in grading.

To implement and sustain such a program, one needs to build community and administrative support and maintain it.

No New Discovery

The idea of hands-on science is not new. In the 1960s and early '70s, the National Science Foundation supported the development of hands-on teaching materials, such as the kits developed in the Elementary Science Study program and the Science Curriculum Improvement Study. Research showed that these materials were better at teaching science concepts and skills than were traditional textbooks. Well-designed materials also allowed all children to experience success in science, including kids who are good artists or communicators or who have superior hand-eye coordination.

Why, then, didn't these programs become the core of instruction? Partly because in most places, these kits were simply turned over to teachers who had little or no idea of how to use them effectively. Because elementary teachers generally have an inadequate science background, they naturally felt uncomfortable with the materials. Student inquiry meant a lot of noise and mess; materials didn't work right or were used up. What's more,

Lopez, R., and J. Tuomi. (May 1995). "Student-Centered Inquiry." *Educational Leadership* 52, 8: 78–79.

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teachers feared that if they didn't cover all the material in the textbooks, their school's scores on the standardized tests would go down. And how do you grade kids for hands-on science anyway?

To this day, in school science closets and basements around the country, old science kits can be found with half the stuff broken or missing, or still in the shrink wrap because teachers were too intimidated to open them.

Finally: Breakthroughs

Not everyone shrank from the problems. Many educators found ways to refurbish the kits and buy replacement parts in bulk, to train teachers, and to grade hands-on science. In 1985, Doug Lapp, an elementary science program designer, founded the National Science Resources Center as a joint organization of the National Academy of Sciences and the Smithsonian Institution. The center, based in Washington, D.C., collected information about schools that had managed to sustain hands-on science programs for years or, sometimes, decades. The center then conveyed that information to other school districts.

About the same time the National Science Foundation began to fund curriculum development for a new generation of kit-based materials. These materials have gone through a rigorous research and development cycle, incorporating the best of earlier programs. They also have benefited from subsequent research in developmental psychology.

Such reforms in science education have been far-reaching. In the many communities that have succeeded in their reform efforts, scientists and engineers, as well as scientific and technical corporations, universities, national laboratories, and science museums have played critical roles. They have generated public awareness and support, and assisted with professional development and fund-raising.

The bottom line is this: We know what works for kids, we have a pretty good idea how to make it work in schools, and the help is out there to make it happen. ■

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Ramon E. Lopez is Director, Education and Outreach Programs, The American Physical Society, One Physics Ellipse, College Park, MD 20742. **Jan Tuomi** is Director, Regional Initiatives in Science Education, National Research Council, 2101 Constitution Avenue, N.W., Washington, DC 20418.

PCS May Be Teaching Kids the Wrong Lessons

BY LAURIE HAYS

Staff Reporter of the Wall Street Journal

Sarah Kahn sees it as the battle of the screens.

In the family room of her New Canaan, Conn., home, three of her children flit from the TV set to the Game Boy to the PC and back again. "I say, 'Turn that TV off.' They go right to the next screen," says Dr. Kahn, a gastroenterologist. "The PC has the same pull as the TV."

Many parents think it's great when their kids flip on the computer, figuring that computers are educational and, at the least, less passive than television. "But here's the bad news: Most educational software isn't, alas, all that educational, and it can have many of the same ill effects as the boob tube."

Certainly PCS have great potential for promoting learning and creativity. Kids with short attention spans or those in need of remedial help can benefit from the lively graphics, sound and novelty of drill programs. Even if a program isn't perfect, when children and parents play it together, the kids get some benefit. And, after all, learning how to use a computer is good preparation for the future.

But PCS can also promote passivity, dull creativity and limit socialization in children, taking away from more important kinds of play, educational experts say. In some circles, fears are growing that a new generation bred in the "pop" PC world will suffer the same effects as the so called TV generation, with some kids emerging unable to reason well or communicate effectively.

"PCS, for the most part, are a debased form of play. It isn't the kind of imaginative play that young kids will indulge in if allowed to use their own resources," says Marie Winn, who in 1977 wrote "The Plug-In Drug," a book on the impact of television on children.

Some education experts believe fully 75% of the hundreds of software titles aimed at children don't teach much at all. Kids aren't "learning" as much as drilling by pointing and clicking. The ideas come from the software rather than the children, who respond by rote rather than by using their own thought processes.

Part of the problem is that even noncomputerized drill work is sharply at odds with "whole language," a popular educational approach that teachers children academic skills through an integrated curriculum.

But even some kids are critical. Eleven-year-old Jessica Djilani fooled around with drill programs at home in Scarsdale, N.Y., but found herself "just sitting there like a vegetable. It's like watching TV. You feel disgusting," she says.

Pat Aufderheide, associate professor of communications at American University, limits TV time for her six-year-old son and four-year-old daughter and is astonished by how "engaged and interested they are in computer games. After her son told her, "This is almost like TV," she realized how addicted he had become and began limiting his PC time, too.

Software makers call their wares "drill for skill," but some doubters prefer "drill and kill" because so many of the titles adopt shoot-em-up game techniques. This simplistic approach requires little direct help from mom and dad.

But that's the point, critics say. "Publishers want something that's easy to run, will catch the child's fancy and doesn't require parental assistance—because that's what will sell," says June Wright, a professor of early childhood education at Eastern Connecticut State University. Adds Joseph Parness, a developer of multimedia titles for Jostens Learning Co., "The majority of educational titles continue to prove to be nothing more than whimsical 'edutainment' products that have evolved into the fast foods of learning."

Reader Rabbit, an enormously popular series, is a frequent target of critics. Published by Learning Co., it has sold more than two million copies since it was first released in 1984, and last year it led the half-billion-dollar-a-year education market. In one of the programs, Reader Rabbit's interactive Reading Journey, a cartoon hare guides preschoolers and older kids through a series of games, sounding out words and hopping through books as children point and click.

All this looks educational, and many children love it. So do parents. Cheryl Truett of Canton, Ohio, says her six-year-old daughter, Shannon, a kindergartner, spends hours on Reader Rabbit and has taught herself to read. Mrs. Truett also finds the PC's electronic baby-sitting role convenient. It gives her time to do housework when Shannon is home in the mornings.

But a recent study of 49 children in Missouri found that those who used Reader Rabbit and similar drill programs for six months at their preschool had a 50% drop in creativity, as

measured by a standardized test, with no statistically significant gains in learning how to read.

The problem is that when words are taught as isolated objects they don't have real meaning, says Susan Haugland, the child-development professor at Southeast Missouri State University who ran the study.

In addition, her study found, children frequently play these games by randomly clicking on words until they find the right ones or memorizing the story, making it seem as though they are reading. Kids also tend to gravitate toward the least educationally useful aspects of a program when left to navigate it on their own.

The study also cited a discouraging addiction factor: Children using these programs, bent on competing to "win," were glued to the screen three times as long as those who used "developmental" software that was less game-like.

While some parents say they don't see the harm, Dr. Haugland opposes using such sophisticated, expensive gear to do the same flash-card job that a piece of paper and pencil can do.

Pat Walkington, vice president at Learning Co., defends Reader Rabbit: "I wouldn't say that it's better than a teacher or a parent, but it's very effective and engaging." A company spokeswoman adds that it beats violent computer games. "It does enhance learning—would you rather have them playing Doom?"

Math is another problem area. At Dr. Kahn's home, the two boys, Sam and Jake, are engaged in a prebedtime game of Math Blaster. The putative point of the game is to practice adding, subtracting and multiplying. But Jake, six years old, says he sees the object as "we get to shoot down spaceships." Nine-year-old Sam likes playing the program, too, but his mother says it's way too simple for him—"a waste of time."

Many educators say they believe children need to learn how to think through math problems rather than simply memorizing a list of answers. Yet "a steady diet of these programs makes you want to memorize and get the right answers," says Douglas Clements, a professor of math education at the State University of New York's Buffalo campus. What's more, after all the multimedia gizmos and games, kids may balk at doing math the boring, old-fashioned way, with pencil and paper.

Social interaction is also lost in most PC play. When children play together or with adults, discussions and disagreements ensue, teaching them to get along and see other points of view, experts say. Alone at the PC that doesn't happen.

Some experts say children can also lose a sense of empowerment with most PC software. Popular titles offer a predetermined set of options, automatically limiting a child's imagination. In small doses, this is probably fine, the experts say, but most children would still be better off sitting down with crayons and paper and making their own pictures or stories—or even, occasionally, doing nothing at all.

When kids play an old board game, they make up their own rules as they go along, notes Ms. Winn, the "Plug-In Drug" author. "Creating their own images helps children work out problems and resolve powerlessness," she says. "On the computer, the machine has all the power to make the rules."

Some Software Nurtures Creativity

BY LAURIE HAYS

Staff Reporter of the Wall Street Journal

For those who believe computers have potential for teaching, there is hope.

At the Edgewood School in Scarsdale, N.Y., 14 fifth-graders sit in pairs in a spacious, brightly lit computer classroom, working on Macintoshes. Using concepts from math class—angles, multiplication, greater-than and less-than variables—they have designed on-screen pinball games and are now testing them.

The projects are a team effort. Jessica, age 11, and Tom, 10, argued at length before finally agreeing to create a soccer game. Each movement required a command, which the children programmed themselves. Their ball now ricochets at a 170-degree angle because, after much trial and error, that angle "looked the most realistic," Jessica says.

The children are pleased with their results, which took them about six hours. "It's my favorite part of the day," Jessica says of computer class. "Both of us hate math, but math on the computer is fun. We look at what we've done and say, 'Aren't we smart.'"

Gerald Crisci, the school district's elementary school computer coordinator, says children should use computers to apply what they have learned to "do" and "make" things. That's why he recommends that kids wait to use computers until they reach the third grade and can apply basic skills. "Computers shouldn't be used for feeding kids information," he adds.

Mr. Crisci has third-graders create snowflakes in 3-D. The fourth-graders are putting together and programming animated zoos, drawing on their study of endangered species in science. Students have to remember fine points, he says, such as the need to avoid putting predators and prey in the same habitat.

After the fifth-graders finish their pinball games, they plan to make bar charts of the books the class has read this year, separating them by title, genre, length and popularity. Earlier this year, they did an immigration project using a database that included real manifests from ships that landed in Boston Harbor in 1840. Every team was given a family, and the goal was to set the family up in the New World with a balanced budget. This required using the database to find jobs, housing and even mates.

In all of the Edgewood School's software, there is very little pointing and clicking and no animated figures that haven't been created by the children themselves. Teachers shun drill software because they believe they can do a better job on basic skills themselves. "We know what we want to teach. The computer doesn't," explains fourth-grade teacher Barbara Black.

Mr. Crisci created most of the curriculum from scratch, using a language called MicroWorld's Logo from Logo Computer Systems Inc. and a software package called ClarisWorks from Apple Computer Inc.'s Claris subsidiary. There isn't much commercially available software that he considers truly educational.

Some industry executives say that is changing. As computers become more powerful and designers get more sophisticated, a new genre is emerging, they say. Multimedia programs that let children write and draw and create simulated villages, cities and their own characters are starting to appear.

Roger Schank, director of the Institute for the Learning Sciences at Northwestern University in Evanston, Ill., loathes the use of animated bears to teach children to read and laments the popularity of putting books on CD-ROM.

The software industry needs to invent a new way of learning, he maintains. He is working on "Broadcast News," a software program that lets kids make a TV news show, incorporating history, math and current events. "We are prepared to do better things," he says, if commercial companies will go along.

Jon Goldman, chief executive of ImaginEngine, a small software company in Mountain View, Calif., started out with a service that encourages children to write letters to characters by mailing back computer-generated responses that appear handwritten. Now he pursues software that will let children design their own computer characters and give them personalities.

"Just because we haven't reached the promised land of software excellence," he says, "doesn't mean that it's a mirage."

Choosing a Program

Some programs that educators recommend:

Primary Grades: My Own Stories, Storybook Weaver, both by MECC; Imagination Express, Edmark; Kid Pix, Broderbund. The Print Shop, Broderbund; Kid Works 2, Davidson.

Middle School: The Students Writing Center, Learning Co; SimTown, Maxis; HyperStudio, Roger Wagner Publishing; Amazing Animation, Claris; Fine Artist, Microsoft; Kid Cad, Davidson; Project Builder, MicroWorld.

High School: SimCity and SimCity 2000, Maxis; HyperCard, Apple; SuperCard, Allegiant.

Note: Most of these programs require adult support.

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